The Engineer

FEBRUARY 6, 1953 28, ESSEX ST., STRAND, LONDON, W.C.2 TWO SHILLINGS

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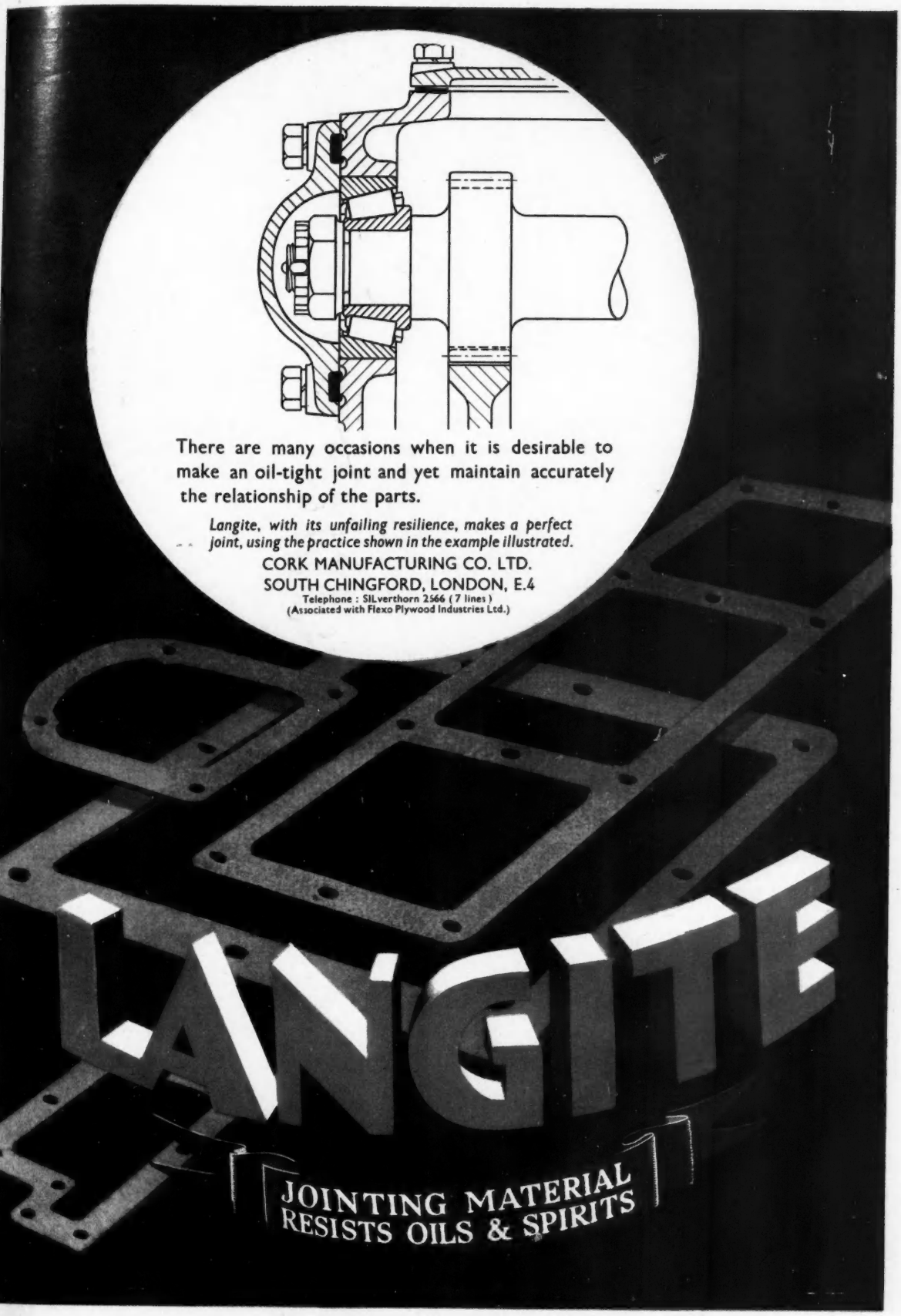
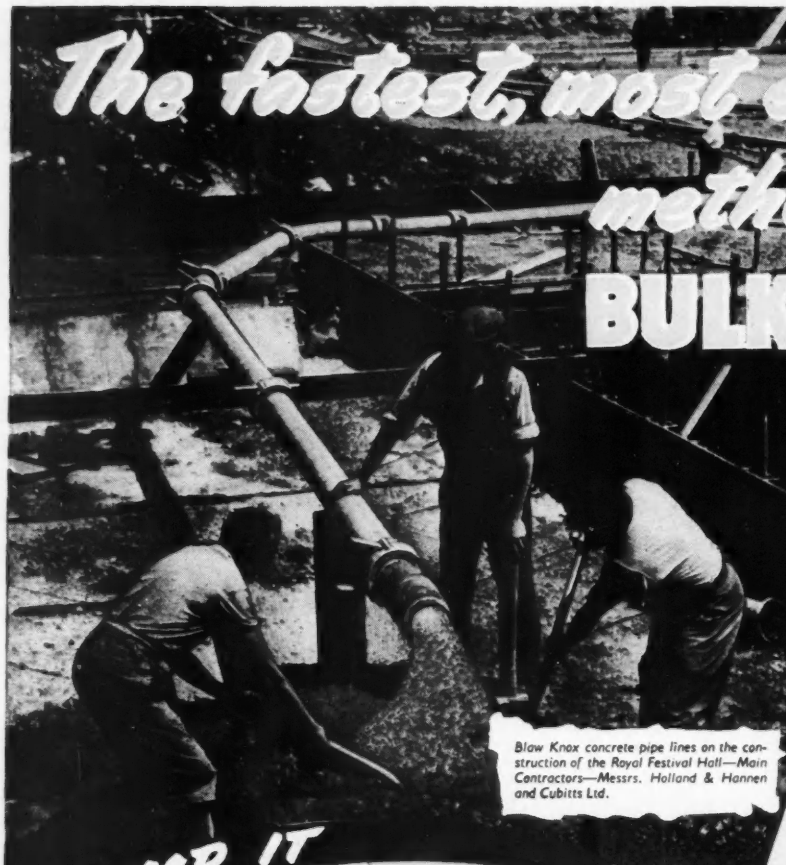

There are many occasions when it is desirable to make an oil-tight joint and yet maintain accurately the relationship of the parts.
Langite, with its unfailing resilience, makes a perfect joint, using the practice shown in the example illustrated.
CORK MANUFACTURING CO. LTD.
SOUTH CHINGFORD, LONDON, E.4
Telephone : SILverthorn 2566 (7 lines)
(Associated with Flexo Plywood Industries Ltd.)
LANGITE
JOINTING MATERIAL
RESISTS OILS & SPIRITS

The fastest, most economical method of placing BULK CONCRETE giving



Blaw Knox concrete pipe lines on the construction of the Royal Festival Hall—Main Contractors—Messrs. Holland & Hannen and Cubitts Ltd.

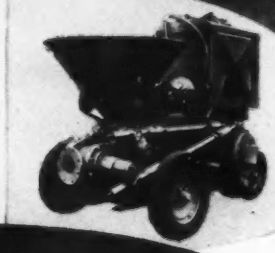
BETTER
placing of high quality concrete at the lowest cost per cubic yard.

BETTER
placing on awkward sites—uphill, downhill and underwater . . . traversing highways and railway tunnels without obstructing traffic.

BETTER
placing without rehandling problems . . . no chutes, hoists, towers, buckets, cranes, etc.

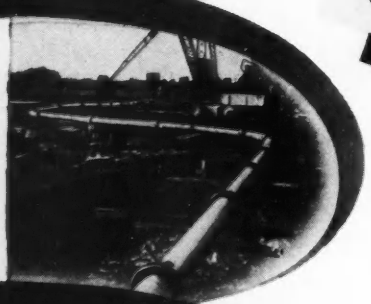
BETTER
utilisation of manpower — with one man more concrete can be placed than by a whole team using old fashioned methods.

PUMP IT



Basic component of the system is the BLAW KNOX portable, two speed, heavy duty, single acting horizontal piston pump. Capacity 15-20 cubic yards of concrete per hour.

PIPE IT



BLAW KNOX Concrete Pipelines comprise 6" steel pipes in various lengths up to 10' and simple, quick-acting couplings with rubber seatings for fast assembly and dismantling. During pumping the pipeline is completely filled, concrete moving through in synchronous impulses in an excellent state of uniformity.

PLACE IT

Concrete is poured straight into the forms, exactly where it is needed.

Blaw Knox engineers will be glad to advise on the application of the Concrete Pump to specific jobs.

BLAW KNOX

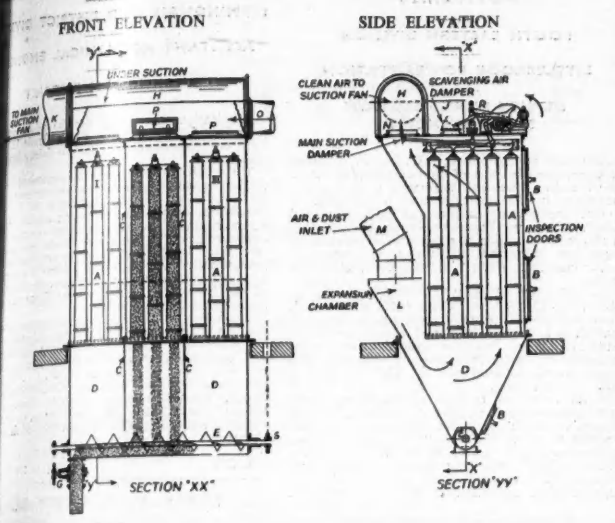
BK.63

BLAW KNOX *Concrete by Pipeline*

BLAW KNOX LIMITED; 90/94 BROMPTON ROAD, LONDON, S.W.3

Telephone: KENsington 5151 Cables: BLAWNOX, LONDON Grams: BLAWNOX, SOUTHKENS, LONDON

AREA OFFICES IN BRISTOL, LEAMINGTON SPA, LIVERPOOL AND YORK. REPRESENTATION IN BELFAST, CARDIFF, DUBLIN AND GLASGOW, AND ALL PRINCIPAL CITIES OF THE WORLD



VISCO-BETH AUTOMATIC *Dust Collectors*

Why they are almost 100% efficient

For the recovery of valuable powders, the "Visco-Beth" automatic dust collector is unequalled. This collector will give a continuous efficiency of over 99 per cent. twenty-four hours a day when dealing with the finest impalpable dust.

In the "Visco-Beth," the inherent difficulty of bag filtration, time required for removing the recovered dust from the filter tubes, has been eliminated by ingenious mechanical shaking gear operating in conjunction with a reverse current of "scavenging" air. This method renders the whole operation continuous and automatic.

The collector casing is divided into compartments each of which contains a battery of textile tubes, suspended vertically, the shaking gear and the mechanically operated valves being on top of the casing.

All the filter tubes in each compartment are cleaned at short intervals ; each compartment being isolated in turn by the valves, while the rest of the dust separating equipment continues to function in the normal manner.

While a compartment is isolated, the tubes are sharply shaken to dislodge the dust adhering to the cloth. At the same time, a current of clean air passes through the cloth in an opposite direction to the normal flow.

By means of this positive action, the released dust falls to the spiral conveyor for discharge through the rotary valve to a convenient receptacle.

The compartment with the cleaned tubes then goes back into circuit automatically, the next one is shut out and the tubes cleaned, and so on, in rotation. The cloth tubes being kept free from accumulated dust operate at a uniform efficiency.

A more detailed description is given in our Publication No. 482 "Modern Dust Collection and Fume Removal," a copy of which will be gladly sent on request.

VISCO ENGINEERING CO LTD. STAFFORD RD. CROYDON

THE ENGINEER

ESTABLISHED 1856

Vol. 195 No. 5063

FEBRUARY 6, 1953

28 Essex Street, Strand, London, W.C.2

Telephone : CENtral 6565 Telegrams : Engineer Newspaper, Estrand, London

Published every Friday Registered as a Newspaper

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NOTICE TO READERS

All letters intended for insertion in 'The Engineer' or containing questions should be accompanied by the name and address of the writer, not necessarily for publication, but as a proof of good faith. No notice whatever can be taken of anonymous communications. No undertaking can be given to return drawings or manuscripts; correspondents are therefore requested to keep copies.

SUBSCRIPTIONS

U.K. & ABROAD £5. 10. 0. CANADA £5. 5. 0. annually including postage. Every subscriber is entitled to one FREE copy of the DIRECTORY & BUYERS GUIDE as published—extra copies 5s. each post free.

CLASSIFIED ADVERTISEMENTS

LINEAGE RATE (Under 1 inch):—2s. 6d. per line of 6 words. Minimum 10s.

INCH RATE (1 inch and over):—Rates per insertion per single column inch—1 insertion—30s. 6 insertions—27s. 13 insertions—26s. 26 insertions—25s.

USE OF BOX NUMBER: The charge is 2s. including the cost of re-addressing replies, which are forwarded immediately on receipt. N.B. There is no Charge for Box Nos. under "Situations Wanted."

WORDING OF ADVERTISEMENTS: Approximately the first 25 letters of each advertisement are set in heavy type. Advertisers are therefore advised to begin their advertisements with the words they want emphasized.

Advertisements received by Mid-day Tuesday will appear in the issue of Friday the same week. Orders must be accompanied by a remittance.

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PUBLIC APPOINTMENTS

THE UNIVERSITY OF LIVERPOOL

DEPARTMENT OF ELECTRIC POWER ENGINEERING

ASSISTANT LECTURER OR LECTURER

Applications are invited for the post of ASSISTANT LECTURER or LECTURER in the Department of Electric Power Engineering. The initial salary for an Assistant Lecturer will be £450 per annum, with allowance for age, experience and qualifications; the initial salary for a Lecturer will be within the range £550–£750 per annum, according to qualifications and experience.

Applications, stating age, academic qualifications and experience, together with the names of three referees, should be received not later than 28th February, 1953, by the undersigned, from whom further particulars of the conditions of appointment may be obtained.

STANLEY DUMBELL,
Registrar.

E7219

UNIVERSITY OF NOTTINGHAM

DEPARTMENTS OF CIVIL AND MECHANICAL ENGINEERING

DRAUGHTSMAN

DRAUGHTSMAN required to work under the direction of the Professor of Engineering. Salary up to £500 p.a. Application form and conditions of appointment may be obtained from the undersigned.

H. PICKBOURNE,
Registrar.

E7075

UNIVERSITY COLLEGE HOSPITAL

PART-TIME CONSULTING ENGINEER

University College Hospital, Gower Street, W.C.1, requires the services of a PART-TIME CONSULTING ENGINEER (or FIRM), whose duties will include the planning and execution of building works and their engineering services. The post will have a retaining fee and professional fees will be payable.

Applications, giving full professional details, should be submitted to the undersigned within two weeks of the appearance of this advertisement.

T. F. W. MACKEOWN,
Administrator and Secretary.

E7224

UNIVERSITY COLLEGE OF SOUTH WALES AND MONMOUTHSHIRE

LECTURER IN ENGINEERING

Applications are invited for the post of LECTURER IN ENGINEERING, which will become vacant on 1st October, 1953.

Salary scale, £550–£50–£1100 p.a. Initial salary up to £800 p.a., according to qualifications and experience. Eight applications stating age, academic qualifications and experience should be sent to the undersigned not later than 14th March, 1953.

(Signed) E. R. EVANS,
Registrar.

Cathays Park,
Cardiff.

E7205

MIDDLESEX COUNTY COUNCIL EDUCATION COMMITTEE

ACTON TECHNICAL COLLEGE, HIGH STREET, ACTON, W.3

MECHANICAL ENGINEERING DEPARTMENT

ASSISTANT (GRADE B)

Required, ASSISTANT (Grade B), with industrial experience and a good knowledge of machine shop work. Preference given to candidates holding National Certificate and who have had some teaching experience.

Forms of application (stamped, addressed envelope), from the Principal, to whom completed forms should be returned within fourteen days of the appearance of this advertisement.

C. E. GURR,
Chief Education Officer.

E7186

HARRIS INSTITUTE TECHNICAL COLLEGE, PRESTON

CIVIL AND MECHANICAL ENGINEERING

LECTURER OR ASSISTANT LECTURER

LECTURER or ASSISTANT LECTURER in Civil and Mechanical Engineering.

Applications are invited for the above post. Candidates should possess a Degree or equivalent qualification and should have had good practical experience. The duties will include teaching in classes included in the Degree and Higher National Certificate Courses.

Salary will be in accordance with the Burnham Scale.

Forms of application may be obtained from the undersigned, and should be completed and returned within two weeks of the appearance of this advertisement.

T. M. NAYLOR,
Principal.

E7249

THE COLLEGE OF AERONAUTICS

BOARD OF ENTRY

The Board of Entry of the College invites applications from suitable candidates for the TWO-YEAR COURSE, which begins in October, 1953, and ends in June, 1955.

Candidates should be of graduate standard, although the possession of a degree is not essential; a good Higher National Certificate is an acceptable standard.

The College, a post-graduate institution, is devoted to the study of aeronautical science and engineering. The curriculum covers the five main subjects of aerodynamics, aircraft design, aircraft electrical engineering, aircraft propulsion and aircraft economics and production. Instruction in the first year is designed to provide students with a broad background of knowledge in all these subjects, with opportunity for limited specialisation in two or three of them. In the second year students specialise more particularly, usually in one subject.

Experiments in the air are an important part of the work, both in the first year, when all students take part in them, and in the second year, when they are linked to the specialist work of the departments.

Students who satisfactorily complete the course will receive the Diploma of the College.

Further particulars and details of the procedure for enrolment may be obtained on application to the Warden, The College of Aeronautics, Cranfield, Bletchley, Bucks.

E7211

CITY OF LEICESTER

EDUCATION COMMITTEE

LEICESTER COLLEGE OF TECHNOLOGY AND COMMERCE

Principal: H. L. HASLEGRAVE, Wh.Sc., M.A. (Cantab), Ph.D. (Lond.), M.Sc. (Eng.), M.I.Mech.E., M.I.E.E.

Applications are invited for the position of HEAD OF THE SCHOOL OF ENGINEERING, duties to commence on 1st January, 1954, at a salary according to Grade IV of the Burnham Committee Report, 1951, for Heads of Departments, at present £1340 by £25 to £1490. It is hoped that the person appointed will join the staff on 1st September, 1953, or soon afterwards, on the Senior Lecturer salary scale (maximum of which is at present £1190), in order to become fully acquainted with the School before assuming full responsibility as Head of it.

Candidates should have completed an apprenticeship, have had good industrial experience, have had teaching experience in a technical college, and should hold an Honours Degree in Engineering at a British University, and be Corporate Members of the Institution of Mechanical Engineers.

Further information and application forms can be obtained from the Registrar, to whom completed applications should be returned by 28th February.

ELFED THOMAS,
Director of Education.

E7240

SURREY COUNTY COUNCIL EDUCATION COMMITTEE

REDHILL TECHNICAL COLLEGE

GRADE B ASSISTANT

Applications are invited for posts of GRADE B ASSISTANT to teach mathematics, science, drawing to National Certificate standard. Candidates should possess an Engineering Degree and have had suitable teaching and/or industrial experience.

Salary (men) £490 by £25 to £765 p.a. (inclusive of special addition), plus additions for approved qualifications and training.

Application forms obtainable from the Divisional Education Officer, 33, London Road, Reigate.

E7262

ADMIRALTY

NAVAL CONSTRUCTION DEPARTMENT

NAVAL ARCHITECTS

The Admiralty require qualified NAVAL ARCHITECTS for unestablished service in the Naval Construction Department in Bath. British subjects in possession of a University Degree (or its equivalent) in Naval Architecture and should have had practical shipyard experience. They will be employed as Design Assistants, grading and salaries will be assessed according to age, qualifications and experience. The salaries for the two grades open range up to a maxima of £875 10s. and £1377 5s. respectively, but only exceptionally well-qualified candidates will be considered for the higher grade.—Application forms from M.O.L.N.S., Technical and Scientific Register (K), Almack House, 26, King Street, London, S.W.1, quoting C632/52A. Closing date 20th February, 1953.

E7214

MINISTRY OF SUPPLY

DIVISION OF ATOMIC ENERGY (PRODUCTION)

SCIENTIFIC OFFICERS

SCIENTIFIC OFFICERS required at Capenhurst, Chester. Post 411—molecular theory of gases and applied fluid mechanics. Post 412—aerodynamics of compressors and high-speed machinery development. Minimum qualifications: Second Class Honours Degree in Physics or (post 412) mechanical engineering or equivalent. Salary £417–£675. F.S.S.U. may be applicable.—Applications to Ministry of Supply, Division of Atomic Energy, (Production), Risley, Warrington, quoting appropriate reference.

E7215

BRITISH ELECTRICITY AUTHORITY

SOUTH EASTERN DIVISION

LITTLEBROOK POWER STATION

DEPUTY POWER STATION SUPERINTENDENT

Applicants should possess B.Sc. Degree or should be Corporate Members of the Institution of Mechanical and/or Electrical Engineers, with extensive experience in the operation and maintenance of modern high-pressure turbine and boiler plant and E.H.T. switchgear. Experience in the administration of a large power station, together with initiative, good organising ability and experience in the control of labour essential. Class "M" Grade 3, £1393 per annum.

CROYDON "A" and "B" POWER STATIONS, MAINTENANCE ENGINEER (MECHANICAL). Applicants should preferably possess B.Sc. Degree or equivalent and must have had experience in the control of labour. Extensive experience in the maintenance of high-pressure turbine and boiler plant and power station auxiliaries essential. Class K, Grade 6, £982 16s. per annum.

N.J.B. Conditions of Service for both positions. Salaries quoted include London allowance.—Applications, on forms obtainable from Station Superintendents at either Croydon "B" Power Station, Beddington Farm Lane, Purley Way, Croydon, Surrey, or Littlebrook Power Station, near Dartford, Kent, should be received by the appropriate Station Superintendent not later than 18th February, 1953.

E7263

NATIONAL COAL BOARD

MECHANICAL AND ELECTRICAL ENGINEERING BRANCH

CONTROL AND SWITCHGEAR ENGINEER

National Coal Board invite applications for a superannuable appointment as CONTROL AND SWITCHGEAR ENGINEER in the Mechanical and Electrical Engineering Branch at London Headquarters.

Although primarily concerned with control of switchgear, the successful candidate will be expected to do other general electrical work. Preference will be given to applicants with some or all of the following qualifications and experience:—Eligibility for Associate Membership of the Institution of Electrical Engineers; experience at a manufacturers' works on design, manufacture and application of all types of mining electrical apparatus; experience of electrical engineering at a coal mine.

The salary will be within a range of £1000 to £1250 per annum, according to qualifications and experience.

Apply in writing, giving full particulars (in chronological order) of age, education, qualifications and experience (with dates), to National Coal Board, Establishments (Personnel), Hobart House, Grosvenor Place, London, S.W.1, marking envelope TT/589. Original testimonials should not be forwarded. Closing date 21st February, 1953.

E7217

CITY OF LEICESTER

CITY ENGINEER'S DEPARTMENT

GENERAL ENGINEERING ASSISTANT

Applications are invited for the following position in the Mechanical Engineering Section of the City Engineer's Department:—

GENERAL ENGINEERING ASSISTANT
Salary A.P.T. Grade V (£595–£645).

Qualifications: candidates should be Graduates of the Institution of Heating and Ventilating Engineers or hold equivalent qualifications. They should be experienced in the design of heating systems and preparation of specifications and should be efficient draughtsmen.

A general knowledge of electrical installations in buildings would be an advantage.

The appointment will be subject to the Local Government Superannuation Act, 1937, and the successful candidate will be required to pass a medica examination.

Applications should be made to the undersigned not later than Saturday, February 21st, 1953.

JOHN L. BECKETT, M.Inst.C.E.,
City Engineer and Surveyor.

Town Hall,
Leicester.

E7250

PADDINGTON GROUP HOSPITAL MANAGEMENT COMMITTEE

PADDINGTON HOSPITAL, HARROW ROAD, W.9

RESIDENT ENGINEER-IN-CHARGE

Applications are invited for the post of RESIDENT ENGINEER-IN-CHARGE, Paddington Hospital, Harrow Road, W.9. Applicants must possess the Ordinary National Certificate in Mechanical Engineering or an equivalent qualification, and have served an apprenticeship in general engineering. A knowledge of operating and maintaining steam boiler plant, calorifiers, heating systems, laundry and kitchen equipment essential. Must also have experience of electrical lighting and low-voltage power installation, and maintenance work, and also general maintenance of buildings.

Salary £500 by £20 to £600 p.a., plus London weighting of £30 p.a. if over 26 years of age, less a charge to be determined for residence.

Applications, stating age, qualifications, experience, together with the names and addresses of three referees, to reach the Secretary to the Committee by 28th February, 1953.

E7243

WEST MIDLANDS GAS BOA

BIRMINGHAM AND DISTRICT DIVI

ASSISTANT MECHANICAL ENGIN

BIRMINGHAM DISTRICT

Applications are invited for the above po the salary for which will be within Grade 12 £865 per annum) of the National Salary Sca Gas Staffs.

The successful applicant will be required to the Mechanical Engineer in the maintenance gasworks plant and the installation of new Candidates should have served an apprentices engineering and have had further experience in engineering and steam plant. Some knowled mechanical handling plant will be an advantage possession of the Higher National Certific Mechanical Engineering or Corporate Membe of the Institution of Mechanical Engineers Engineering Degree is desirable.

The post is superannuable and the successful date may be required to pass a medical exami

Applications, stating age, training, qualifica and experience, together with the names of referees, should be addressed to Mr. J. E. Wak Divisional General Manager, West Midlands Board, Birmingham and District Division, Offices, Edmund Street, Birmingham, 3, to reach within fifteen days of the appearance of this a tisement.

F. H. CURETON,
Secretary to the Boa

E7274

LONDON ELECTRICITY BOAR

CONSTRUCTION BRANCH

STRUCTURAL ASSISTANT AND STRUCTURAL DRAUGHTSMAN

Applications are invited for the above pos in the Construction Branch of the Chief Engin Department in Central London.

Applicants for the position of STRUCTU ASSISTANT should have experience in the d and detailing of reinforced concrete structures, applicants for STRUCTURAL DRAUGHTS should have experience in detailing reinforced crete structures.

The posts are graded under Schedule "D" o National Joint Board agreement:

Structural Assistant as Grade 5, £595 7s £704 11s. p.a.; Structural Draughtsman as Gra £458 to £595 7s. p.a. These figures are inclusi London allowance. Commencing salaries wi dependent upon qualifications and experience.

Application forms obtainable from Establishm Officer, 46/47, New Broad Street, E.C.2, to returned duly completed by 21st February, Please enclose addressed foolscap envelope and Ref. V/1573/EE on all correspondence.

E7

MINISTRY OF WORKS

STRUCTURAL ENGINEERING DRAUGHTSMEN

STRUCTURAL ENGINEERING DRAUGHTSMEN are required in London, at Risley (Warrington), Harwell (near Didcot, Berks), and other cen

Accommodation available for single men Risley and Harwell.

London salary: Draughtsmen, up to £620 annum, starting pay according to age, qualifica and experience; Leading Draughtsmen, £62 £733 per annum. Rates outside London sli lower.

Applicants should be experienced in design a detailing of reinforced concrete or structural work. Work is varied and not confined to stan schemes.

Although not established posts, many have t term possibilities; competitions are held peri ally to fill established vacancies.

Apply in writing, stating age, nationality, ex ence and locality preferred, to Chief Structural neer, W.G. 10/S.1, Ministry of Works, Abell H John Islip Street, London, S.W.1.

E7

BRITISH LEGION INDUSTRIE

MAIDSTONE

INDUSTRIAL GENERAL MANAGE

INDUSTRIAL GENERAL MANAGER req to take charge of rehabilitation factories emp two hundred and fifty men, the maiority being abled. Industrial experience. Knowledge of neering or carpentry and allied trades an advan Preference given to ex-servicemen. Service available.

Applicants should submit details of experience &c., together with names of three referees and anticipated, to the undersigned within ten days date of this advertisement.

A. A. HOWICK,
Secretary-Administrat

E1009

THE INSTITUTION OF CIVIL ENGINEERS

ROCKEFELLER FOUNDATION BURSARIES

PUBLIC HEALTH ENGINEERING

Applications are invited from graduates and expecting to graduate this year for ROCKEFELL BURSARIES for Post-Graduate Study and Res in Public Health Engineering.—Full details obtainable from the Secretary of the Institu Great George Street, London, S.W.1. Applica must be received by 31st March, 1953.

E7

THE ENGINEER

FEBRUARY 6, 1953

The East Coast Floods

OUR readers will doubtless be aware, from the many reports in the daily press during the past week, of the extent of the very severe flood damage in East coast areas which was caused by exceptional conditions of wind and tide last week-end. At the time of going to press, it is too early to give a complete account of the extent of the damage. From the engineering point of view, however, the statement made in the House on Monday by Sir Thomas Dugdale, Minister of Agriculture, is of particular interest. Sir Thomas pointed out that last Saturday evening an abnormal tide surge created havoc on both sides of the North Sea. Major breaches in sea defences took place along the English coast from East Yorkshire to Kent, he noted, and the emergency arrangements developed by his department after the 1947 floods came into play immediately. As events developed, Sir Thomas continued, it was clear that the disaster was far beyond the scope of first-aid measures. Saturday morning's tide, he said, was not abnormal, but the evening's tide was two hours earlier than predicted and maintained itself at a high level for several hours ; at all places along the East coast it was six feet and more above the predicted level and was accompanied by strong winds and heavy wave action. Sir Thomas explained that the defences along the Essex coast were maintained above the level of the record tides of 1949, but on Saturday night, tides were between 1ft and 2ft above that level. As a result, he went on, sea defences over a great length of coastline were overtopped and breached in many places and the sea had penetrated far inland. Some 250,000 acres had been flooded by sea water, and in the Essex area alone there had been some 280 breaches in sea defences. It was already clear, Sir Thomas said, that the need for reinstatement of sea defences along a great length of coastline would present one of the greatest civil engineering problems the country had ever had to face. Practical steps were already being taken and he hoped to make a further announcement in a few days time. We understand that the combination of meteorological conditions which caused the catastrophe were, very briefly, as follows. A deep depression moved over the North Sea from the Shetlands, causing north-westerly gales, and by midnight on Saturday the storm centre was nearing Hamburg ; the spring tides were thus increased above their predicted level by the inshore winds and the consequent piling up of water in the southern part of the North Sea.

Loss of M.V. "Princess Victoria"

AT 7.45 a.m. on the morning of Saturday of last week, the British Railways motor vessel "Princess Victoria," sailed from Stranraer for Larne, and it is with regret that we record that the ship subsequently sank with heavy loss of life. At the time of sailing a total of 123 passengers and a crew of forty-nine were on board, and within an hour of leaving a radio message was received stating that the ship was in difficulties and not under command. Exceptionally heavy weather in the Irish Sea, it is stated, damaged the cargo doors in the stern of the ship and caused flooding in the engine-room and gave the ship a list. This steadily increased and at about 1 p.m., after drifting helplessly half way across the Irish Sea, the "Princess Victoria" sent out a wireless message saying that the ship was on her beam ends and was about to be abandoned. The call for assistance was answered by the destroyer "Contest," which sailed from the Clyde, and other vessels, including the Donaghadee lifeboat, which picked up a number of survivors. Of the 172 people on board, only forty-four were saved. The "Princess Victoria" with the "Princess Margaret" operated the Scotland-Ulster service; the former ship, which was completed in 1947, had a gross tonnage of 2694, accommodation for 1515 first and third-class passengers, and space for about fifty motor vehicles. She had a length between perpendiculars of 305ft 6in by 48ft beam and a depth to the promenade deck of 28ft 6in. The propelling machinery, designed to give the ship a speed of 19 knots, consisted of two Sulzer seven-cylinder trunk piston two-stroke oil engines, having a total output of 5100 h.p. at 275 r.p.m.

Institution of Incorporated Plant Engineers

THE Institution of Incorporated Plant Engineers was founded seven years ago, its predominant aim being to improve the professional status of plant engineers. Its articles of association describe plant engineers as those capable of taking executive responsibility for the design, installation, maintenance or control of fixed or mobile plant. Consequently, the membership of the Institution includes such "fixed" plant engineers as the chief engineers in charge of engineering plant in industry, in municipal and service establishments, together with their assistants or maintenance engineers, and also such "mobile" plant engineers as the chief engineers and maintenance engineers in charge of contractors' plant. On Friday evening last, the Institution held its first annual dinner at the Café Royal, London, under the chairmanship of the president, Mr. G. A. Rooley. The principal toast of the evening, that of "The Institution," was proposed in an excellent after-dinner speech by Sir John Maud, K.C.B., Permanent Secretary to the Ministry of Fuel and Power, who referred to his Ministry's concern for those "four great horsemen of the Apocalypse—coal, gas, electricity and oil." Plant engineers, Sir John said, were people of national importance, practising true economy of money and manpower as, by trying continually to get the best possible value out of the plant under their care, they were required to conserve the country's fuel resources and to put them to the most effective use. In acknowledging the toast, the President spoke of the necessity for facilities which enabled those with specialised engineering interests to come together and announced that in seven years the Institution's membership had grown to nearly 3000. Its education scheme which was now operating would result, he felt, in the average age of the membership being reduced. Mr. L. G. Northcroft proposed a toast to "The New Honorary Members," to which response was made by Mr. J. Wilson, the final toast being that of "The Guests," which was proposed by Mr. R. S. Davenport and acknowledged by Sir Norman Kipping.

The Institute of Refrigeration

NEARLY 400 members and their guests attended the fifty-third anniversary banquet of the Institute of Refrigeration, which took place at the Savoy Hotel on Wednesday, January 28th, with the president, Sir Charles G. Darwin, as chairman. Major Gwilym Lloyd George was to have proposed the toast of "The Institute of Refrigeration," but he was unable to be present and his speech was read by Mr. I. Grant. The speech commented upon the value of refrigeration in the equable distribution of home-produced food supplies by freezing the surplus of high summer for winter use, and suggested that home meat supplies would be as high as before the war. There would be more work this year, it was asserted, for refrigerated ships which statement was supported by quoting the tonnage of supplies expected from New Zealand, Australia and the Argentine. The president replied and said that the business of the Institute, which was one of the pivotal bodies keeping the country alive, was to improve both technique and machines. He went on to express interest in the School of Refrigeration, which was flourishing, and to discuss the value of extra-mural courses in helping members to keep abreast of the latest developments. Sir Charles recommended that the school should be expanded not only with regard to space, but with regard to studies which could be enlarged to cover temperatures down to the absolute zero. "Science and Industry" was proposed by Lieut.-Colonel Lord Dudley Gordon, who stressed the need for science and industry to go forward hand in hand and the necessity to apply science properly to achieve good results. He emphasised the importance of industrialists making full use of what the scientists provided and reminded those present that food was not the only outlet for the industry of refrigeration. Sir Ben Lockspeiser responded and prophesied that before the century was out the industry would be busy on the problem of getting rid of heat from aircraft. Sir Ben went on to suggest that we did well out of the industrial revolution, but felt that we were not making the most of the scientific revolution, and went on to mention the need for biological refrigeration in relation to world food supplies and also to ask for the co-operation of the refrigeration industry in the practical research being established by the Department of Scientific and Industrial Research.

Imperial College of Science and Technology

QUESTIONS which were addressed to the Chancellor of the Exchequer on Thursday of last week sought information on the Government's plans for the establishment of a technological university. A written reply by Mr. Boyd-Carpenter, Financial Secretary to the Treasury, states that, after consulting the University Grants Committee, the Government proposes to put further resources at the disposal of the University of London for the purpose of major expansion of the Imperial College of Science and Technology. There are now about 1650 full-time students at the College, and the aim will be to raise that number to 3000 during the academic quinquennium 1957–62. It is desirable, the reply continues, that the work of Imperial College shall be so co-ordinated with that of other schools of the University that full advantage can be taken of the whole of the University's resources. For that reason, and in order that the current work of the college may be disturbed as little as possible, the Chancellor has been advised that the expansion should take place around the existing site of the College in South Kensington. The reply goes on to say that this development of Imperial College will be in pursuance of the policy, already announced by the Government, of building up at least one institution of university rank devoted predominantly to the teaching and study of the various forms of higher technology. In addition to this development of Imperial College, the Government proposes to make resources available for further developments in other parts of the country. The Chancellor of the Exchequer has asked the University Grants Committee for advice as to where such further resources might most usefully be deployed. These projects, the reply says, will be additional to the substantial developments of higher technological education which are already in progress in different parts of the country.

Sewage-Sludge Digestion Calculations

By L. B. ESCRITT

No. II—HEAT BALANCE

(*Concluded from page 160, January 30th*)

For those who like precise and elaborate sewage-works calculations, the design of digestion plant must be, in part, a disappointment, for, apart from the details of the mechanical plant, the calculations are unavoidably based on very wide assumptions. Any engineer can, of course, make detailed calculations of quantities of sludge and availability of, and demands on, heat, but he should be aware that the answers he gets are not necessarily as accurate as those obtained by such of his brethren as prefer to save time by using accepted rules-of-thumb. Here the whole subject is discussed and illuminated by specimen calculations.

THE calorific value of sludge gas is in the region of 630 B.Th.U. per cubic foot, or considerably higher than that of coal gas. This value varies from one sewage works to another and from time to time at the same works. An interesting observation was that the calorific value of sludge gas fell during the war by about 30 B.Th.U. per cubic foot, owing to differences in the available food supply and the way in which food was utilised. Sludge gas has now been used for many years in internal combustion engines, and the design of dual-fuel engines—i.e. those capable of being operated on either sludge gas or oil—is well understood.

A rough rule for preliminary design is that about one-third of the heat available from sludge gas is sufficient for heating the sludge in the digestion tanks to the mesophilic range of temperature and maintaining it there. Another rough rule is that if the whole of the gas is used in internal combustion engines, the amount of heat that can be economised from the cooling water and exhaust gases is again approximately one-third of the total. So on the average it can be assumed that all the gas can be used for power purposes and the digestion tanks heated by means of the cooling water and heat collected from the exhaust gases. A gas boiler needs, of course, to be installed to provide heat for the digestion tanks at times when the power plant is not in full operation.

Returning to the example set out in the first article (January 23rd), the quantity of gas available at the rate of 0·8 cubic feet per head of population from a population of 50,000 persons is 40,000 cubic feet per day, and this will provide 25,200,000 B.Th.U. per day. Roughly one-third of this, or 8,400,000 B.Th.U. per day, or 350,000 B.Th.U. per hour, will be required for heating the sludge. The actual amount of heat required, however, varies according to the amount of water in the sludge and the heat losses through the top, bottom and sides of the tank.

Heat Requirements

The following calculations are based on the assumption that the specific heat of sludge is equal to that of water. Actually, it is slightly less, the specific heat of the suspended solids being about 0·28, but as the proportion of solids to water is low, this difference can be neglected.

In the first article of this series the quantity of sludge in the example calculation was estimated at 15,500 gallons per day at 96 per cent moisture content. In the winter the temperature of this sludge would have to be raised from 45 deg. to 86 deg. Fah. Therefore, the heat required for raising temperature of sludge is :

$$\frac{15{,}500\times 10}{24}\times(86\text{ deg.}-45\text{ deg.})$$

$$=265{,}000\text{ B.Th.U. per hour.}$$

The next heat demand calculation is for the amount of heat required to make up radiation losses. This sounds equally straightforward and simple as any of the calculations given so far, and the first impression of an engineer used to dealing with heat exchange and insulation problems would be that this calculation should be capable of being made accurately, not being based on broad assumptions. But this is not, in fact, the case, for the thermal conductivities of some of the component parts of the external surfaces of digestion tanks have not been determined by experiment. Therefore, guesses have to be made with the possibility of a considerable degree of error.

For this reason, and the fact that usually ample heat is available, the heat losses from a large number of digestion tanks in this country have been estimated by rule-of-thumb based on simple observations of existing tanks. The method of testing tanks has been to operate the tanks at normal working temperature for a period, then to stop admitting fresh sludge, stop heating and measure the fall of temperature over a period of several days. The figures so obtained, plotted on a graph, give a fair indication of the initial rate of temperature drop.

These experiments show that the initial loss of temperature per day during the winter varies from one site to another between the limits of 0·4 deg. and 1·0 deg. Fah. The former figure was usual for cork-insulated tanks, the latter for a tank buried completely under the ground in waterlogged subsoil. No information is available as to how long the buried tank had been in operation before the test was made. Therefore, it is possible that the subsoil round the tank had not been completely heated at the time of the test, which would mean that an unduly high result had been obtained.

The heat loss at the well-known West Middlesex works is understood to be 0·7 deg. Fah. per day, or the average of the above extremes, and this could be recommended as a basis for calculation, being safer than the figure of 0·5 which has been used in some instances. Then the rule-of-thumb example calculation is as follows :—

Capacity of primary tank, 37,500 cubic feet.

Therefore:

$$\text{Loss of temperature}=\frac{37{,}500\times 62\tfrac{1}{2}\times 0\cdot 7}{24}$$

$$=68{,}300\text{ B.Th.U. per hour.}$$

Then :

	B.Th.U. per hour
Demand for heating sludge	265,000
Demand for maintaining temperature	68,300
Total heat demand	333,300

It will be seen that, according to this method of calculation, the total heat demand is slightly less than one-third of the heat available.

Detailed Calculation of Heat Losses

The second method of estimating heat loss is to calculate theoretically the losses through the component parts of the tank according to the materials of construction, degree of exposure, &c. For this purpose simple conditions will be assumed, to avoid complication of the calculation. The tank is 43ft 9in diameter and 25ft deep ; is covered by a gasholder having an area of 1500 square feet (including exposed water surface) ; has a floor area of 1500 square feet resting just on the ground, and has vertical walls of 3440 square feet area, all of which is exposed to the air.

Loss of heat is in direct proportion to the area exposed, and also to the difference of temperature from hot side to cold side of the material traversed, and it is in inverse proportion to the sum of the heat-resisting properties of the component materials. The heat-resisting property of a solid wall of any single material is in proportion to the thickness of the wall divided by its conductivity, or $\frac{b}{K}$.

Thus the formula for calculating heat loss is as follows :—

$$Q=A\left(\frac{t_1-t_0}{\frac{1}{f_1}+\frac{b}{K}+\frac{1}{f_0}}\right)$$

where

Q = B.Th.U. per hour.
A = square feet area of wall, roof or floor.
t_1 = degrees Fahrenheit, hot side.
t_0 = degrees Fahrenheit, cold side.
f_1 = surface coefficient, inside.
f_0 = surface coefficient, outside.
b = wall thickness in inches.
K = thermal conductivity in B.Th.U. (of 1in thickness of material) per superficial foot per hour per degree Fahrenheit.

Where a space is occupied by a liquid or gas, or a liquid or gas in contact with the surface, the transfer of heat to or from the surface is complicated by the movement of the fluid. In immediate contact with the surface is a film of fluid which, moving slowly, has considerable heat resistance while, away from the surface, convection currents rapidly transfer heat. Where liquids or gases are in contact with surfaces, surface coefficients (f_1, f_0, &c.) determined by experiment, have to be used. The heat resistance at the surfaces is generally so much greater than the heat resistance in the mass of liquid or gas in the remaining space that the latter can be neglected.

Example Calculation

Commencing with loss of heat through gasholder, the main resistances to heat loss are the surface resistance of the gas at point of contact with the sludge, the surface resistance of the gas in contact with the underside of the gasholder, and the surface resistance of the air on the outside of the gasholder. It is usual to neglect the surface resistance of the water, although, if scum is present, this may be considerable. The metal of the gasholder is so thin and its conductivity so high that this resistance also can be neglected.

As to the values of the surface resistance of gas and air, no figure has been given for methane, and those quoted for air are varied, but the following are suggested as being reasonably accurate :—

For sludge to methane : $\frac{1}{f}=0\cdot 6$

For methane to underside of gasholder $\frac{1}{f_1}=0\cdot 6$

For gasholder to outside air (horizontal surface, average wind conditions) $\frac{1}{f_0}=0{\cdot}25$

Then, allowing a winter air temperature of 35 deg. Fah., loss through gasholder roof :

$$Q=\frac{A(t_1-t_0)}{\frac{1}{f}+\frac{1}{f_1}+\frac{1}{f_0}}$$

$$=\frac{1500\ (86-35)}{0{\cdot}6+0{\cdot}6+0{\cdot}25}$$

$=52{,}800$ B.Th.U. per hour.

Dealing next with the walls, let us assume that these consist of reinforced concrete of 1 : 2 : 4 mix, 12in thick, insulated with 2in of cork and having vertical faces of 3440ft super completely exposed to the air. The following table gives a few values for the thermal conductivities of solid materials ; others may be obtained from textbooks and the publications of the Department of Scientific and Industrial Research :—

Material	K
Brickwork (damp)	9
Concrete, 1 : 2 : 4	10
Concrete, foamed slag	2
Timber	1
Cork	0·35
Felt	0·27
Clay (damp)	8
Loam	10

In the case of the vertical surface of a wall, $\frac{1}{f_0}$ can be taken as 0·4. Then, as film loss from sludge to walls is neglected, the loss through the walls is :

$$Q=\frac{A(t_1-t_0)}{\frac{b_1}{K_1}+\frac{b_2}{K_2}+\frac{1}{f_0}}$$

$$=\frac{3440\ (86-35)}{\frac{12}{10}+\frac{2}{0{\cdot}35}+0{\cdot}4}$$

$=24{,}000$ B.Th.U. per hour.

There is an added complication in calculating the heat loss through the floor, because this will vary considerably according to how long the tank has been in operation. When a new tank is freshly filled with sludge, the bottom of the tank and the ground are cold and, for some considerable time, will slowly heat up, taking heat from the sludge in the tank. Eventually, when the ground has become heated, it will act as an immensely thick mass of insulating material.

In several instances calculations have been made in which it was assumed that the ground was permanently cold, and the only heat resistances allowed were those for the concrete floor plus a factor for heat resistance between exterior surface of concrete and ground. The writer considers that this method is unsound in that, for the greater part of its working life, the tank is resting on heated ground ; therefore, the subsoil should be considered as an insulating material of great thickness (except where there is an appreciable flow of subsoil water).

It is obvious that this alternative supposition could involve very complex theory, for the heat, escaping from the under surface of the tank to the surface of the ground surrounding it and thence to the air, must follow various devious routes, far from easy of determination and integration. The writer has therefore assumed that, until a better theory is put forward, the distance taken through the ground should be assumed as equal to the radius of the tank, plus any distance that the outer edge of the floor may be below ground level.

Then, assuming a floor thickness of 12in and a clay subsoil, the calculation for the loss through the floor becomes :

$$Q=\frac{1500\ (86-35)}{\frac{12}{10}+\frac{21{\cdot}875\times12}{8}+0{\cdot}25}$$

$=2200$ B.Th.U. per hour (approx.)

The sum of the heat demands then becomes :

	B.Th.U. per hour
Loss through roof	52,800
Loss through walls	24,000
Loss through floor	2,200
Total radiation losses	79,000
Demand for heating sludge	265,000
Total heat demand	344,000

(which, in this instance, is not so very different from the rule-of-thumb calculation).

Secondary Tank

So far the calculations have dealt with heating the sludge and maintaining the temperature in the primary tank only. The conditions in the secondary tank have still to be investigated.

It is not uncommon practice to let the hot sludge pass from the primary tank to the secondary tank, but to economise in cost of equipment by not providing for maintaining the temperature in the secondary tank. The amount of this temperature drop and its effect on digestion can be investigated as follows.

Assuming that the secondary tank is constructed exactly the same as the primary tank, the total heat losses are 79,000 B.Th.U. per hour, when the difference of temperature is 86—35, or 51 deg. Fah. Therefore, the heat loss is :

$\frac{79{,}000}{51}=1550$ B.Th.U. per hour per degree Fahrenheit difference of sludge and winter air temperatures.

Then, if t_2 is the temperature of the sludge in the secondary tank, the heat loss equals :

$$1550\ (t_2-35)$$

But this loss is made up by the heat brought into the tank, which is :

$$\frac{15{,}500\times10}{24}\times(86-t_2).$$

Therefore,

$$\frac{15{,}500\times10}{24}\times(86-t_2)=1550\ (t_2-35)$$

Therefore,

$$t_2=76 \text{ deg. Fah.}$$

Digestion and Gas Production

Now let us investigate in detail the digestion and gas production in each tank. Numbers of experiments have shown that gas is given off after the first few hours of digestion at a very high rate, but that the rate tails off rapidly. For this reason it is not always necessary to collect gas from secondary tanks because by far the greater part of the gas is given off in the primary tank, and what remains to be given off in the secondary tank does not justify the cost of gas-tight roofs. The following table is fairly representative of the amount of gas given off for different periods at 86 deg. Fah. expressed as a percentage of the total produced in thirty days :—

Days detention	Percentage of gas produced in 30 days
1	16
2	30
4	50
6	65
8	76
10	83
12	88
14	92
16	94
18	96
20	97
25	99
30	100

The figure assumed for gas production was 0·8 cubic feet per head of population per day. Then a population of 50,000 persons provides 40,000 cubic feet of gas per day. The amount of gas produced works out, both in theory and practice, at 21·5 cubic feet per pound of dry solids digested. Therefore, dry solids lost in thirty days is $\frac{40{,}000}{21{\cdot}5}$

$=1860$ lb, or 186 dry gallons.

In the primary tanks the sludge is detained at 86 deg. Fah. for fifteen days (see first article). During this period 93 per cent of the gas available is given off (see table). Therefore dry solids lost :

$$186\times0{\cdot}93=173 \text{ dry gallons per day.}$$

As the total quantity of dry solids was 620 gallons per day (see first article) 447 gallons of dry solids per day are passed to the secondary tank.

Conditions in the secondary tank are different from those in the primary tank, for as there is little disturbance due to emission of gas, and it is contrary to practice to provide any mechanical stirring, bands of water, of comparatively low suspended solids content, collect at or near the surface. If this supernatant water is efficiently drawn off, the remaining sludge is rendered more dense and a figure of perhaps 94 per cent moisture content may be assumed.

Then, the quantity of sludge per day discharged from the secondary tank

$$=\frac{447\times100}{(100-94)}$$

$=7450$ gallons per day of sludge.

and, as the capacity of the tank is 234,000 gallons, the detention period is 31·4 days, which is a sufficiently long period for digestion to the required standard at a temperature of 76 deg. Fah. Thus heating of the secondary tank is not necessary.

Heat Exchange

Other calculations which may have to be made are those which relate to the exchange of heat in the installations for sludge heating. Several methods are used for sludge heating, of which the following are the most usual :—

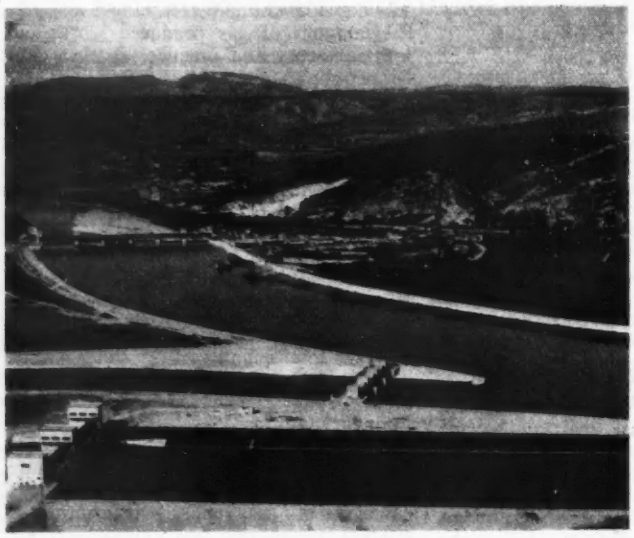
(1) Internal heating of the tanks by fixed or moving coils of hot water pipes.

(2) External heating by drawing off sludge and passing it through calorifiers or heat exchangers.

When the sludge is heated by fixed coils, there is little motion of the sludge film in contact with the outer surface of the heating pipes ; also, these pipes develop an external crust. For these reasons a large heating surface is necessary. A recommended figure is 1 superficial foot of external surface of pipe per 10 B.Th.U. per hour per degree Fahrenheit difference between hot water and sludge temperature. For this purpose a maximum water temperature of 130 deg. to 135 deg. Fah. is usual.

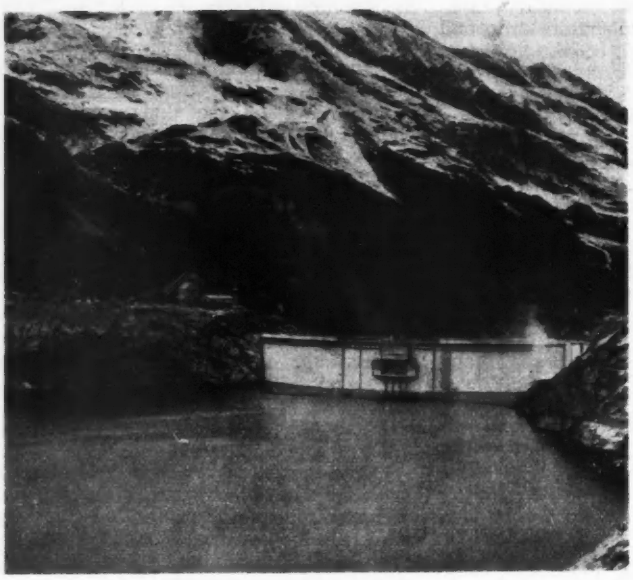
When sludge is heated in an external heat exchanger, the rate of exchange is much greater, for the sludge is kept in motion at a velocity of 3½ft to 4ft per second, and this greatly reduces the film resistance. Consequently, figures of 50 to 60 B.Th.U. per hour per square foot of pipe surface in contact with sludge per degree Fahrenheit difference of temperature between sludge and heating water are allowed. Heating water temperatures in the region of 160 deg. Fah. have been used.

SOME FRENCH HYDRO-ELECTRIC SCHEMES OF 1952



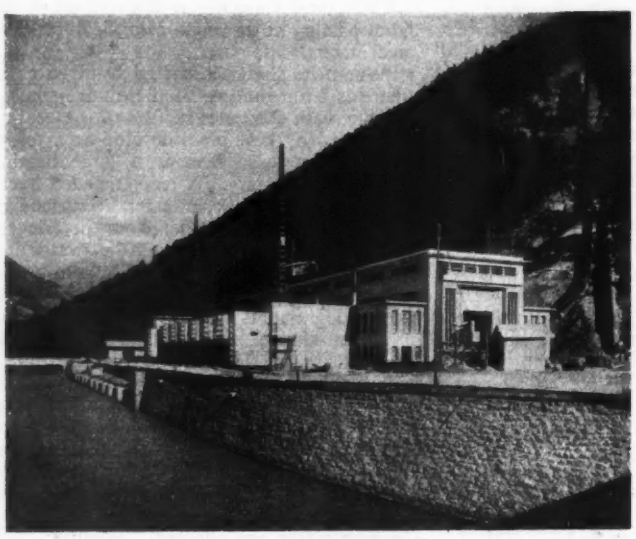
Headworks of the Donzere Canal

Power Station, Spillway and Lock—Donzere-Mondragon

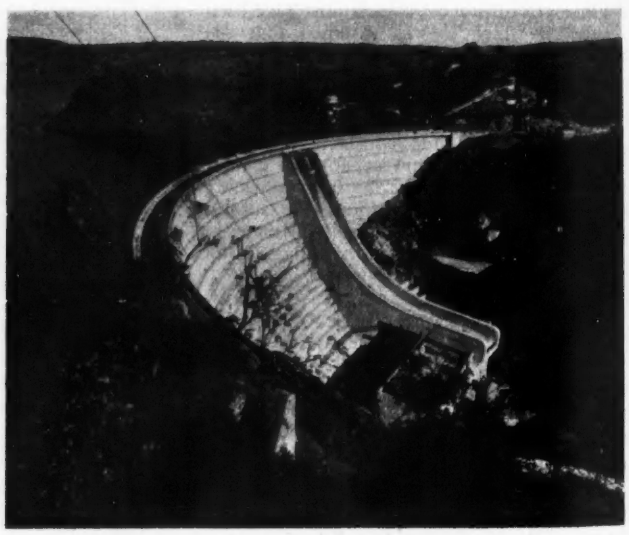


Tignes Dam and Reservoir

Tignes Dam from Downstream



Malgovert Power Station



Bort Dam and Power Station

Some Foreign Civil Engineering Schemes of 1952

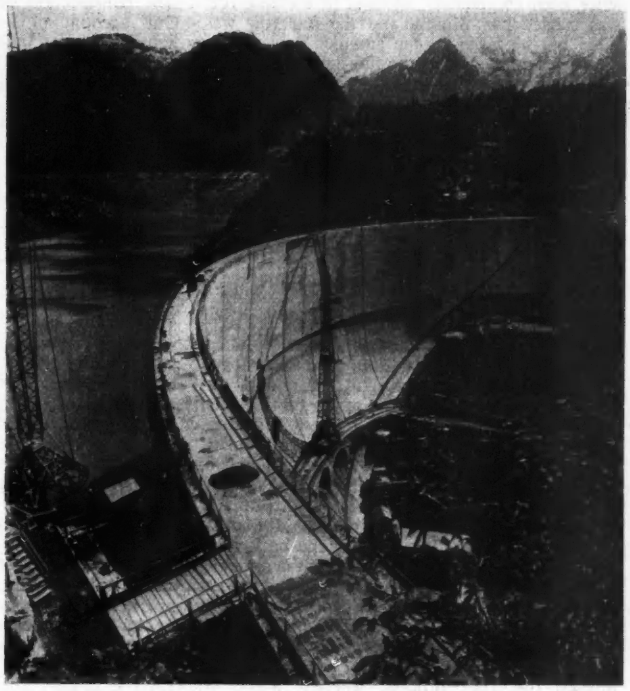
No. II—(*Concluded from page 166, January 30th*)

THE year 1952 was a notable one for hydro-electric construction in Europe. As stated in the first part of this article, the power stations at Harspranget, in Sweden, and Donzere-Mondragon, in France, were inaugurated during the year, and work was in progress on several other schemes of comparable magnitude, including the high-head power stations at Malgovert (France) and Santa-Massenza (Italy), mentioned later on. A comparison between the first two of these developments is of interest. Both will produce about the same amount of power annually—1800 million kWh at Harspranget and 2000 million kWh at Donzere—yet the cost of the former was of the order of £7,000,000 and of the latter about £75,000,000. The reasons for this difference are not far to seek. At Harspranget, an exceptionally favourable site—both from the aspects of the head and flow available and the good quality of the rock for tunnelling—was developed on the River Stora Luleälv by the economical methods which are typical of Swedish practice. A rock-fill dam (maximum height 148ft) was built with the spoil from the tunnelling works, the power station being underground vertically below the dam, with a penstock leading down to each machine. A long unlined tail-race tunnel, 49ft by 43ft in cross section, was driven back to the river at the tail-race level. Three large turbo-alternator sets, each of 96MW, have been installed in the power station, and provision has been made for a fourth. The gross head is 351ft. The figure given above for the cost does not include the cost of transmission lines. It may be recalled that power is transmitted from this station at 380kV. Harspranget lies within the Arctic Circle, and the power is required in the South of Sweden; with the transmission lines taken into account, the cost rises from about £24 per kilowatt (corresponding to the figure already given) to £55 per kilowatt. A description of the scheme was given in our issue of March 28th last.

By contrast, the Donzere-Mondragon scheme, on the Lower Rhone, utilises a head of only 23m, through a diversion canal 28km in length. The canal is also used for navigation, and the works included the provision of a lock, operating over the full head (maximum 26m); a barrage was built across the Rhone to maintain the intake level, and the canal has two entrances, one for navigation and one for the extra flow necessary for power production, each with its own barrage. The power station, spillway and lock are all built together, 17km from the canal intake. There are to be six 50MW sets in the power station, of which three were put into service at the opening last October. The re-routing of communications over the canal was a major problem, and a number of road and railway bridges have been built as part of the scheme. Our illustrations show, first, the double intake works with the navigation entrance in the foreground and the power canal behind it, and in the background the barrage across the Rhone; and second, the power station, six-pass spillway and lock. These works have already been described in THE ENGINEER in some detail (December 22 and 29, 1950, and October 24, 1952), so that no further details will be given here. The extensive nature of the scheme, the facilities given for navigation, and the communication works will, we think, give an idea of its complexity in relation to the simpler requirements and layout at Harspranget.

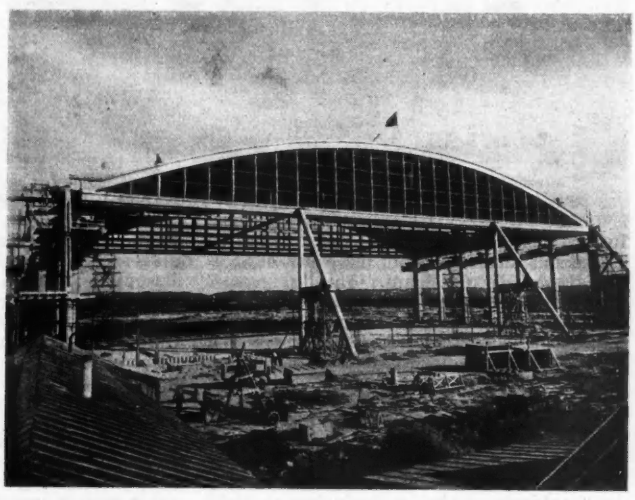
A project somewhat similar in its general layout and comparable in size with the Donzere-Mondragon scheme was completed at Ottmarsheim, on the Rhine, in 1952, and was brought into service last autumn. This scheme was described in our issues of June 6th and 13th last, and, as with the other French hydro-electric schemes mentioned below, it was built by Electricité de France (the Donzere-Mondragon scheme was built by the Compagnie Nationale du Rhone). The power station has an installed capacity of 140MW in four similar sets, a head of 16·4m, and will generate some 1000 million kWh annually. The canal is 14km in length and there are two locks close to the power station at the downstream end of the canal. The points of particular technical interest in the design and construction of the scheme include the layout of the spillways, of which there are four, passing in sluices through the power station itself. Thus the flow may pass through either turbine or spillway without disturbing conditions in the canal. Vacuum concrete was used extensively for the slabs lining the canal, and the plant on the site for the manufacture of the slabs was of considerable interest.

However, apart from these two very large, but similar, low-head schemes, the French hydro-electric industry had several other outstanding schemes which were completed, or nearly so, during the year. Considerable publicity was given, in the spring, to the evacuation of the village of Tignes in the Alps, due to the filling of the large reservoir formed by Tignes dam.



Forte Buso Dam

This scheme was fully described in THE ENGINEER of December 21 and 28, 1951, but one or two principal points are again given here. The dam is an arch structure with a maximum height of 590ft. Its crest length is about 1000ft and its concrete volume about 850,000 cubic yards, the useful capacity of the reservoir being 187,000 acre-feet and the top water level 5872ft above sea level. The value of this considerable storage at



Construction of Shell Roof Hangars at Marignane

such a high level was considered to be equal to 44 per cent of the total capacity of French hydro-electric reservoirs at the beginning of last year, expressed in terms of equivalent electrical energy. Les Brevieres power station, with three 31MW Francis turbine sets and an output of 183 million kWh of firm power annually, is situated just downstream of the dam, and below it there is a forebay for the main power station of the scheme at Malgovert.

Malgovert power station, which is illustrated on page 196, has an installed capacity of about 280MW in four similar 70·4MW sets, each consisting of two horizontal Pelton wheels driving an alternator. The head is 2460ft and some 800 million kWh of firm power will be generated annually.

The photographs of Tignes dam reproduced on page 196 were taken last October, and the dam has since been completed. Storage in the reservoir was started last March, and the reservoir was filled by the large Alpine summer flows up to about three-quarters of the full height, i.e. up to the level of the relatively "green" concrete of the summer's work. One turbo-alternator set was in service at Les Brevieres last December, and the second was due to be put in service then, with the third to be completed in the summer of this year. The first of the two penstocks leading to Malgovert power station was completed, and the second is due for completion next summer. By the end of the year, the diversion works and the first penstock had been successfully tested, and the first two turbo-alternator sets were in service. It is expected that the two other sets will be in service by next autumn.

In the Massif Centrale, the first turbo-alternator set at Bort power station, on the Dordogne River, was put into service at the end of the year. There are to be two Francis turbine sets, each of 100MVA capacity, in this power station, which is built across the downstream side of Bort dam, as shown in the illustration above. There is also to be a subsidiary 35MVA set, supplied from diversion works on a tributary, the Vaussaire, and discharging into the main reservoir above the dam, against the back pressure of the reservoir head. The dam is an arch-gravity structure with a height of 393ft and a length of 1280ft; it was described and shown in cross section in our issue of September 16, 1949. The dam is of particular interest to engineers in this country as its construction utilised the Trief process, whereby about 70 per cent of the cement normally required in the concrete was replaced by wet-ground blast furnace slag. This process is to be used for the Loyne and Cluanie dams of the North of Scotland Hydro-Electric Board. The "ski-jump" spillway passing over the power station roof may be noted in the illustration. During construction a number of steel lattice towers and beams were erected to cover the area of the dam, to provide, in effect, a pair of crane rails. Travelling cranes, spanning between the two lines of beams, were then employed to emplace the concrete. A telpher line was incorporated on the lower chord of the beams and concrete skips were hauled from the batching plant to the travelling cranes by electrically-driven vehicles running along the telpher line. Permanent precast facing blocks were used to replace shuttering.

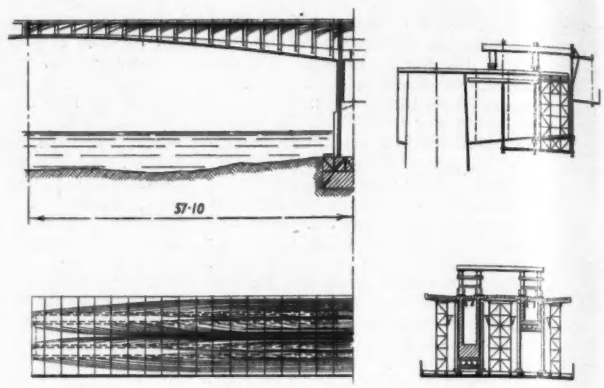
Long Span Shell Roofs

We have recently described in these columns various examples of aircraft hangars under construction in this country, which have made use of several different structural materials—aluminium, prestressed concrete and reinforced concrete. At the beginning of the year under review the erection of a novel hangar structure was completed at the airport of Marignane, near Marseilles, which makes an interesting comparison with the new construction here. Our account of these hangars is based upon a description given in the *Bulletin of the Association Professionelle des Ingénieurs des Ponts et Chaussées et des Mines* Yet another medium—the shell roof—was employed in this case. The shells were cast on the ground and when completed, they were jacked up into their final positions.

Two illustrations of the hangars under construction are shown on page 197. The complete structure consists of two hangars, each with a clear span of 100m (328ft), a clear depth of 60m, and a clear height of 19m; a structure rising to the height of the springing of the shells takes up the space of 18m between the two hangars, and various smaller buildings have been built at the side and back of the block thus formed.

Each of the two principal shell roofs comprises six secondary shells in the transverse direction, as one illustration shows, each with a rise of 2·2m at the centre of the span. The general thickness of the shell is 6cms and the rise of the main span is 12m. Prestressed concrete ties span across the principal direction, carried below the ribs at the junctions of the secondary shells. These ribs, together with stiffening diaphragms of which there are ten spaced along each secondary shell, ensure continuity in the reactions of the roof. Seven columns on each side of the hangar carry the roof, and longitudinal wind forces are taken by four raking struts at the rear, which are shown in our second illustration; there are various subsidiary structural members inside the shell, for instance, to transmit the wind forces to these struts. Transverse wind forces are taken up by the rigid frame of the building between the two hangars. Each of the two shell roofs is fixed at one corner, with provision for expansion at the remaining column heads.

One set of shuttering was used successively for each of the twelve subsidiary shells of the two roofs. Tensioning of the tie beams was carried out in stages to prevent movement at the springing when the shutters were struck. The columns consisted of precast members 1·08m in height of two sorts—a core and a "U"-shaped outer skin. When the complete roof was to be erected, 300-ton jacks were placed on the lowest core members of each column and the structure lifted, in five steps, a height of 1·08m. A "U"-shaped element was then slid into position and took the weight of the roof until the next stage of lifting was started, when the whole procedure was repeated. The column was completed by concreting the open end of the emplaced "U"-elements with vacuum concrete. Erection of each roof took thirty days, the weight lifted being 4300 tonnes.



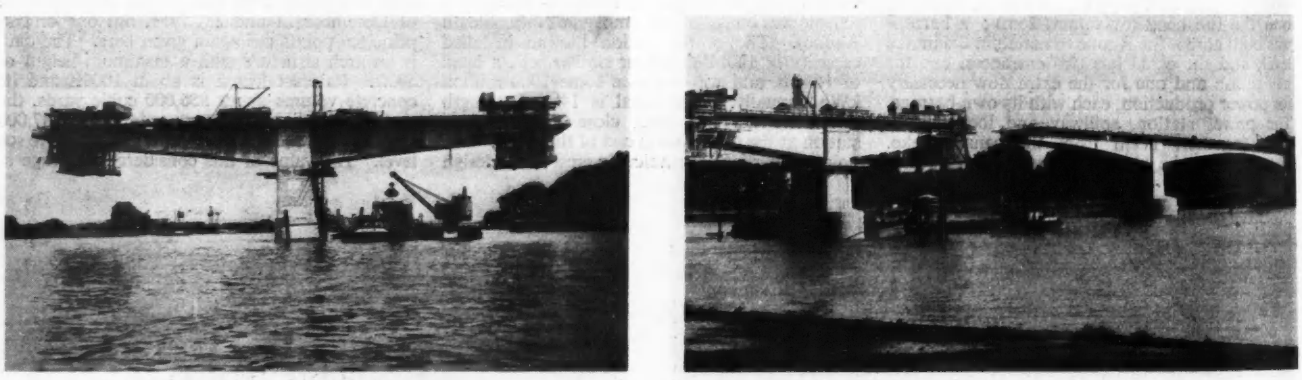
Details of Worms Bridge

An interesting development of shell roofing also occurred in 1952, in Germany. A description has been given in *Bauplanung und Bautechnik* of factory roofing consisting of precast shell roofing elements, each 16m in span and 2·5m wide. The shell is 5cm in thickness, and there is a central rib stiffening the element; the rise is just over half a metre. Apparently no difficulty was experienced in transporting these elements to the site and erecting them.

Italy

Hydro-electric construction in Italy during 1952 also included much of general interest and two schemes are briefly mentioned here, but further details will be given in an article to be published in these columns shortly. The illustration on page 197 shows the Forte Buso dam on the Travignolo River, a tributary of the Avisio, in the Eastern Alps, east of Trento. The dam has been built for S.M.I.R.R.E.L., an aluminium company, and forms the reservoir at the head of a series of power stations. It is an arch-gravity structure 461ft in height with a base width of 164ft. The joint round the perimeter of the dam—a feature common to many recent Italian dams—may be clearly observed on the downstream face.

The power station of Santa-Massenza, which is also in the northern Alps, to the west of Trento, reached an advanced stage of construction last year. This underground power station is to be supplied from two reservoirs in



Prestressed Concrete Cantilever Bridge across the Rhine at Worms

the Sarca River catchment. The principal supply is from Lake Molveno, under a head of between 590m and 460m, and is to operate four 70MVA and two 35MVA Pelton wheel turbo-alternator sets. The second and smaller reservoir is to supply a 25MVA Francis turbine set under a head of 203m. The two 35MVA Pelton sets are each pumping sets, and when the load conditions are favourable, water will be pumped from the lower to the higher reservoir. The storage in Lake Molveno is to be used for peak load generation and also for year-to-year storage, to even out power generation in hydrologically bad years. The whole scheme includes extensive diversion works in a large catchment area, with several subsidiary power stations. At Santa-Massenza itself, about 750 million kWh will be generated each year.

The Amsterdam-Rhine Canal

In our issues of June 20th and 27th last an account was given of the Amsterdam-Rhine canal, which was opened by Queen Juliana of the Netherlands on May 21st. The canal consists partly of an enlargement of an existing one—the Merwede canal—from Amsterdam to Jutphaas (near Utrecht), but from Jutphaas to the Waal at Tiel it is an entirely new work. Construction of this scheme was started before the war.

As a result of the new canal the journey from Amsterdam to the frontier town of Lobith is 40km shorter, and it is estimated that twenty-eight shipping hours are saved. The new canal is of commodious dimensions, with a depth of 4·2m and widths varying from a minimum bottom width of 33·4m. The bridges across the canal are all fixed high-level structures. There are four locks, but most vessels will only have to pass through two. One of the locks is at Tiel, at the entry to the River Waal. At the crossing of the River Lek there is a lock at each side of the river, but one of them will be closed for only a few days each year as the river levels dictate. The fourth lock is on a branch of the canal leading to the Lek. The locks are very large structures, each having a width of 18m and lengths of 225m for the two subsidiary locks and 350m for the two main ones. Of the two main locks, the Irene lock has three lifting gates, and the Bernhard lock has a lifting gate at its head and three pairs of mitre gates dividing it into lengths of 90m, 170m and 90m.

An interesting part of the canal design is the crossing of the River Lek. To avoid silting of the canal from the river and to maintain the required depth at the crossing, the river was narrowed down by training walls to pass through a central channel only, at times of low flow. On each side of this channel an elliptical basin was formed, with the arm of the canal leading into it. The flow of the river induces a current, flowing round each of these two basins, and in this manner the river flow is kept substantially separate from the canal.

Germany

We have drawn attention in these columns to some of the bridge construction which has been in progress in Germany since the war, notably to various slender box girder bridges built with high-tensile steel. Recently a number of interesting prestressed concrete structures have been erected in that country, of which one example is given below.

Exponents of prestressed concrete will find much of interest in the design and construction (these two aspects can hardly be considered apart in this particular structure) of the Nibelungen bridge, which was constructed in 1952 over the River Rhine at Worms. The bridge is of prestressed concrete and has three cantilever spans, each between 330ft and 370ft in length, and a width of 45ft. As with most of the bridge construction carried out on the Continent in recent years, the bridge replaces a structure which was destroyed during the war. The foundations of the old bridge have been used to carry the new structure, which could be accommodated on them safely, although it is 10ft wider than its predecessor. The new bridge at Worms is the first concrete bridge to be erected over the navigable part of the river, all the neighbouring and previous bridges being of steel.

The general conception of the bridge is apparent from the various illustrations reproduced herewith. Each span of the bridge consists of two cantilevers, each extending from the pier or abutment to the centre of the span. Construction started at each pier and proceeded outwards in steps, on each side, as shown in the photograph reproduced opposite. A working gantry was cantilevered on the end of the completed section of the bridge and a new section, 10ft in length, was cast on to the end of the existing work, with the help of shuttering supported by this gantry. When the new section was complete the gantry was moved out into position for the next section. At each stage prestressing bars passed from the older work to the new section, and when the latter had matured sufficiently the bars were tensioned so that, structurally, it became part of the completed cantilever. Couplings were used to join on the lengths of prestressing bars required as the work progressed. At each new section half of the bars were coupled. About five or six days' work was needed at each position of a gantry, but three gantries were used throughout the construction, so that a length of about 5ft of the bridge was built each day.

One of the diagrams shows the bridge in cross section, and it will be observed that there are two box beams with the decking spanning between them and cantilevered on each side. The depth at the centre of the span is only 8ft 2in, which increases to a maximum of 21ft 4in at the supports. The soffit slabs of the box beams vary in thickness, as the diagram indicates ; the four side walls are each 14in thick, and the decking slab is 10in to 12in in thickness. The positions of the prestressing rods can also be clearly seen in the illustration. They follow, in plan and elevation, the lines of principal stress, and are anchored in sections, as indicated previously ; there are 105 sections in the complete bridge. The total prestressing force at each bridge pier is about 9700 tons, which is obtained from 468 rods.

The rods are of 1in diameter, " Spannbeton-stahl Sigma 60/90 " steel. The minimum compressive stress specified for the concrete was 6400 lb per square inch, but the strength recorded from site tests was between 7100 lb and 7800 lb per square inch. One of the illustrations shows the floating concrete plant and the lattice tower at the pier, used for hoisting the concrete.

Only about 600 tons of steel were required for the entire structure. Also, one of the principal economies aimed at in the design was, of course, the elimination of centering, which, it is pointed out, may account for up to a third of the total cost of a bridge for long spans. The method employed in this case is claimed to be both simple and economical. It is not without interest to recall the well-known prestressed concrete bridges built by Freyssinet over the Marne ; in those designs precast elements, successively assembled and tensioned, were employed to avoid the use of centering.

The Nibelungen bridge has been built on the " Dywidag Spannbeton " system, as it is called, which has been introduced and employed on several structures in Germany by Dr.-Ing. Finsterwalder, chief engineer of Dyckerhoff and Widmann, K.G., of Munich, the builders of the bridge.

The Use of Canal Linings in American Irrigation Schemes

(By our American Correspondent)

In 1946 the U.S. Bureau of Reclamation established its lower cost canal lining programme, an interesting research project aimed at the development of new and more economical canal linings, improved lining construction methods and an investigation of canal seepage losses. The importance of this programme is emphasised by the fact that of a total of 15,650,000 acre-feet of water supplied to irrigation projects of the Bureau in 1949, some 3,900,000 acre-feet were lost through seepage from canals and laterals.

THE more important reasons for lining irrigation canals which, under certain conditions, will justify the expense of constructing the lining are considered by the U.S. Bureau of Reclamation to be: to reduce losses of water from the canal ; to prevent damage to lowlands by seepage from the canal ; to reduce operation and maintenance costs ; to increase the capacity of the canal ; to reduce construction costs ; and to prevent failure of the canal. Consideration of any one or more of these factors may justify the cost of lining a canal, and the dominating factor may dictate the type of lining to be installed. The Bureau has carried out a considerable amount of research on this problem, under its lower cost canal lining programme, and some of the experience it has gained is outlined in the paragraphs below, where each section is devoted to a different kind of lining. An ideal canal lining, it is pointed out, would be watertight, be moderate in cost, prevent the growth of weeds, resist the attack of burrowing animals, be strong and durable, be adaptable to the construction of a shape and finish providing maximum hydraulic efficiency, and have a reasonable amount of flexibility. No canal lining material now in use by the Bureau possesses all of these characteristics, but each possesses most of them to a greater or lesser degree.

Concrete Linings

It was realised early in the analysis of Portland cement concrete canal lining that a big factor contributing to high cost was the rigid requirements of the Bureau specifications. In pre-war years there had been ample justification for continued efforts to approach perfection in canal lining construction when the cost of small refinements was almost negligible. However, following the last war, such restrictions as " straight-edge " alignment and " super-smooth " finish of concrete surfaces added considerably to the cost of concrete linings. Accordingly a concerted effort was made to alter the Bureau specification requirements to eliminate all refinements which were judged not necessary from an engineering standpoint.

The use of mechanised equipment for final trimming of the subgrade and for placing concrete lining dates back many years. Until recently, however, such equipment has generally been operated on steel rails placed along the canal berms, or banks. To reduce the cost the specifications were relaxed to permit a departure from the established alignment of 2in on tangents and 4in on curves, and a departure from the established grade of 1in. This brought about the development within the last four years of several items of equipment used for more economical construction in small canals and laterals.

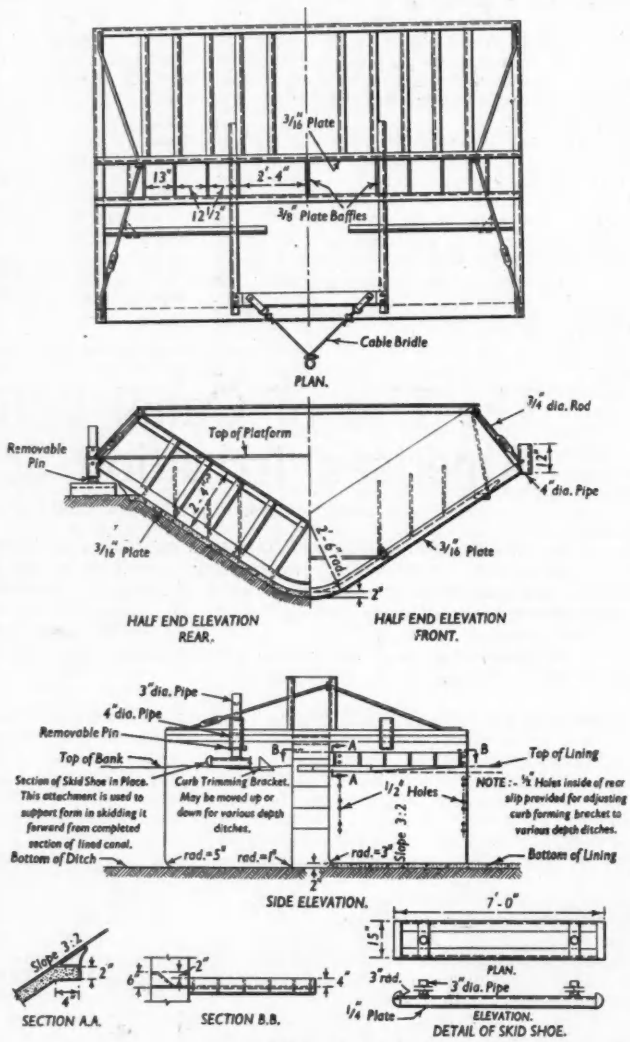
One new device used extensively by the Bureau of Reclamation for lining small canals and laterals is the " subgrade-guided slip-form," which is supported directly on the subgrade without the use of rails. Such a device had been developed and used on the Umatilla project in 1915, but little use was made of it in the years which followed until Clyde E. Shields, an engineer on ths staff of the Gila project in Arizona of the Bureau of Reclamation, developed one of similar design in 1946. The Shields slip-form was so successful for lining small ditches that the idea was soon adopted on other projects. The rate at which lining can be placed with either the subgrade-guided slip-form or the larger, rail-mounted equipment, is limited almost entirely by the rate at which concrete can be

mixed and supplied to the form. Because subgrade-guided slip-forms ride on the subgrade, they are not adaptable for use with steel-reinforced lining.

Details of the Shields subgrade-guided slip-form are shown in the illustration herewith. The forward portion, or skid pan, is shaped to the subgrade and guides the unit as it is towed by a tractor equipped with a side boom and operating on one bank. The rear portion, or slip-form proper, is shaped to the finished lining surface. Behind the skid pan and ahead of the slip-form is a trough for receiving the concrete and distributing it uniformly on the subgrade. Several smaller modifications are in use by the Bureau in lining small laterals and farm ditches. The maximum size canal in which the subgrade-guided slip-form can be successfully used has not been definitely established. It is believed that the form becomes less practicable as the cross-sectional area of the canal exceeds 50 or 60 square feet, and that the probable maximum area is reached at about 100 square feet.

Several methods of mixing and supplying the concrete to subgrade-guided slip-forms have been used with varying degrees of efficiency, but the best results have been obtained by using mechanical equipment which dumps the batch directly into the slip-forms. The illustration opposite shows a travelling plant mixer in operation in conjunction with a subgrade-guided slip-form, the dry aggregate and the cement being placed in a windrow on the embankment ahead of the mixer. An experimental trial on the Gila Canal resulted in average placing rates as high as 4000 square yards per day, compared with rates of 600 square yards per day for truck-mounted mixers employed on the same canal.

The larger slip-forms, which are supported on rails have been in general use in America for about fifteen years. Such equipment is now being used to place many miles of 3in to 4in concrete linings in main canals of unprecedented size on the Central Valley and Columbia Basin projects in California and Washington, respectively. The rate of progress in such large canals requiring 10 to 12 square yards of lining per linear foot of canal, now often exceeds 1000ft per day.



Form for Lining Small Canals

In most cases the improved hydraulic characteristics resulting are not considered sufficient to justify the expense of hand finishing. Furthermore, many canals become silted with use or the surface of the lining becomes covered with moss or algæ, which to a large extent renders ineffective any efforts to produce an extremely smooth surface by hand finishing. Under present practice, concrete linings designed by the Bureau of Reclamation range from 2in to 4½in in thickness. The 2in thickness is generally confined to smaller canals and laterals, while the average thickness of linings on the larger canals is about 3½in. Pre-war Bureau canal lining specifications allowed no thickness tolerance, but current revised specifications allow a 10 per cent variation in thickness, provided the average thickness is maintained. Lining thicknesses slightly less than the recommended 2in minimum have proven adequate under certain favourable conditions. Many miles of concrete lining 1½in thick have been and are being placed economically in small laterals and farm ditches of the south-western states and are giving satisfactory service.

It has been found that a primary requirement for a concrete canal lining, particularly if unreinforced, is a firm foundation which will eliminate as far as possible the danger of cracking or faulting due to settlement of the subgrade. Undisturbed soils are usually satisfactory as a foundation without special treatment, but all fill material which will support the lining must be compacted prior to trimming and lining. The excavation and final preparation of the subgrade for hard-surface linings in small canals is now usually done by special ditchers. Occasionally canal dredging or cleaning equipment has been adapted to the preparation of the canal subgrade.

The benefits of steel reinforcement in concrete canal lining have been debated for many years. Some engineers have contended that steel reinforcement in concrete lining is justified on the basis of longer serviceability and reduced maintenance costs. Others believe that the possible benefits are not commensurate with the added cost and increased construction difficulties. During the last war and following it, the scarcity and accompanying high cost of reinforcing steel brought about a more serious consideration of the question. It was observed that a possible saving of 10 to 15 per cent in the cost of concrete and mortar linings could be realised by the elimination of the reinforcement. Accordingly, a detailed study was made and it was decided that, except under conditions where safety is involved, steel reinforcement may be omitted and a saving thus effected. Another important reason for omitting reinforcement from concrete linings is that subgrade-guided slip-forms are practical only with unreinforced linings.

It has been estimated that the average bid price of reinforced concrete linings 3in to 4in thick in 1946 was about 3 dollars per square yard, and that bid prices for unreinforced concrete linings of the same thickness installed in 1949 and 1950 averaged about 2·20 dollars. This reduction in price has been accomplished in spite of steeply rising wage rates and material costs, and has resulted directly or indirectly from modifications in Bureau specifications, including the elimination of reinforcement. The actual costs of the Bureau's unreinforced linings constructed by contract since December 31, 1946, have ranged as follows :—

Thickness	Cost per square yard (dollars)
2in and 2½in...	2·43 to 3·88
3in and 3½in...	2·30 to 2·94
4in and 4½in...	2·42 to 3·19
5in	4·11

These costs include all lining operations and lining materials, whether furnished by the Government or the contractor, and include final trimming but not the canal excavation. Final trimming is included in the cost of concrete lining because this operation would not be re-required for an unlined canal or for certain other linings.

"Shotcrete" Linings

"Shotcrete" is the term used in America to designate a Portland cement mortar which is forced under air pressure through a nozzle on to the required surface. It has proved suitable for both lining and resurfacing of irrigation canals and ditches and, in particular, for the lining of laterals and farm ditches. However, although many miles of "shotcrete" lining have given years of satisfactory service, particularly in the south-western states, this type of lining is not generally considered as desirable or as economical as slip-form-placed concrete for large schemes. Not only is the rate of progress for shotcrete lining very slow by comparison, but "shotcrete" 1½in thick usually costs as much as 2in of concrete if conditions are favourable for using slip-forms.

"Shotcrete" is usually placed to a thinner section than concrete. Perhaps the chief reason for this practice is that the lining is "built up" to the desired thickness by successive passes of the spray from the hose nozzle, and this building-up process is both time-consuming and expensive. "Shotcrete" linings placed by the Bureau of Reclamation are now usually 1½in thick. However, linings of other thicknesses have been placed for comparison, and "shotcrete" linings of 1in thickness in the canals of the Salt River Valley in Arizona have performed satisfactorily for twenty years.

The cost of "shotcrete" canal lining, including trimming of the subgrade, for 1½in unreinforced "shotcrete" lining installed since the last war has ranged from 2·39 dollars to 3·05 dollars per square yard. The lining thickness subgrade conditions, operating characteristics, and temperature conditions appear to be the principal factors affecting service life. Linings of 1in "shotcrete" reinforced with light wire mesh have been used extensively in canals of the Salt River Valley in Arizona for many years. These canals are used the year round and although some cracking and heaving occur, failures have been few. Prompt repairs have resulted in a satisfactory low-cost lining.

"Asphaltic Concrete" Linings*

Inasmuch as asphalt is comparatively inexpensive and is manufactured in many grades and compositions, numerous variations are possible in its application to the lining and waterproofing of canals. Accordingly, as part of its programme to lower the cost of canal linings, the Bureau of Reclamation has investigated the use of a considerable number of asphaltic linings. The two types which are showing the best promise are

* The American terminology for asphaltic construction is used in this description.

asphaltic concrete and buried asphalt membranes. Asphalt-cement, or some derivative of it, is the basic material used in all asphaltic canal lining. Hot-mixed asphaltic concrete, which has long been used to advantage for street and highway paving, was given early consideration by the Bureau to determine its possibilities as a low-cost, satisfactory lining material; it has been found to be particularly well adapted to the smaller canals and laterals, which permit the use of the inexpensive subgrade-guided slip-forms, but it can also be economically placed by rail-guided equipment.

Subgrade preparation for asphaltic concrete, which involves trimming to relatively wide tolerances, can be accomplished with equipment of rather simple design. The same machinery as that used for trimming subgrades for Portland cement concrete linings is often utilised. A carefully proportioned mixture of sand, gravel and asphalt-cement is mixed in a central plant, usually at a temperature of about 325 deg. Fah. in batches of 1000 lb to 2000 lb, and delivered to the canal in dump trucks. Subsequently the plastic hot mix is deposited in the slip-form by a clamshell bucket, as the equipment moves along the canal to be lined. The material, which retains heat well, is diverted to the sides and bottom of the canal by wings built into the slip-form, and the mix is struck off by a template to allow sufficient thickness for later consolidation. Compaction is accomplished by a weighted ironing plate fastened to the bulkhead behind the strike-off screed. No joints are required except at points where the lining joins structures or where a "lay" is started. Since no curing, sealing or other treatment is required, the lining is ready for use immediately after cooling.

Because of the plastic nature of asphaltic concrete, some types of weeds will penetrate the lining. In fact, some plant growth is actually promoted by the heat-absorbing property of the black surface. Therefore, treating of the subgrade with a soil sterilising agent has been found advisable.

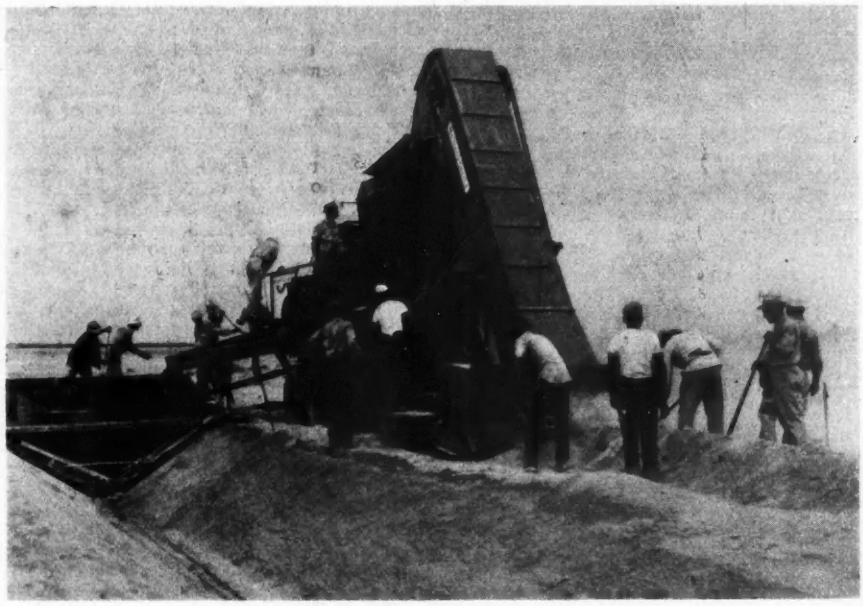
The earliest installation of asphaltic concrete lining by the Bureau of Reclamation was made in May, 1939, and consisted of two short sections of 3in lining in the Contra Costa Canal in California. Other small installations followed, but the total amount of asphaltic concrete placed by the Bureau prior to the initiation of its lower cost canal lining programme in 1946 was very small. These early installations were placed mostly by manual methods, but some use was made of rail-mounted slip-forms. With few minor exceptions the linings have been durable and are still in use to-day. The first large-scale use was made in the Pasco lateral system in Washington in 1947. This installation consisted of 88,160 square yards of 2in lining placed by a subgrade-guided slip-form. The asphaltic concrete mix was designed to produce a high creep resistance on side slopes, a high workability and impermeability. A 60–70 penetration asphalt-cement, with well-graded sand and gravel, was used in most of the lining, but a small portion contained 50–60 penetration asphalt for comparison. The unit cost was 2·49 dollars per square yard, including final trimming of the subgrade and all lining materials and operations. Some minor repairs to the lining have been required to date, but it is generally in good condition.

During 1950, competitive bids were taken for both asphaltic and Portland cement concrete lining involving 88,150 square yards on small laterals of the Riverton project in Wyoming. Despite the use of an evaluation factor based principally on a shorter anticipated life for the asphalt lining, the bid for asphaltic concrete was the lower. The lining, 2in thick, was placed in 1951 using slip-form equipment. Since some of the canal soil contained appreciable amounts of weed seeds and roots, a soil sterilising agent was used in selected areas. The unit cost was 2·27 dollars per square yard, including the final trimming, all materials except the soil sterilising agent, and all operations except canal excavation.

Buried Asphalt Membrane Linings

The idea of a buried asphalt membrane evolved from earlier unsuccessful attempts to cover the surface of a canal with a membrane. It was discovered that the asphalt membrane needs protection from actinic radiation, heat, air, and such mechanical injury as results from the hoofs of cattle. The buried asphalt membrane lining developed by the Bureau consists of a special asphalt layer, about ¼in thick, sprayed in place at high temperature to form a waterproof barrier, which is held in place and protected by a layer of earth and gravel. The canal section is over-excavated an amount equal to the thickness of the covering. After rough excavation of the subgrade, the surface is prepared by light dragging and rolling, to give a smooth subgrade surface which facilitates the construction of a uniformly thick impermeable membrane. The special catalytically blown asphalt used has a very low temperature susceptibility, a high degree of toughness and a long life. After the asphalt has been heated to about 400 deg. Fah. it is applied to the subgrade at a pressure of about 50 lb per square inch by spray nozzles, using either hand sprays, multiple sprays or multiple spray bars. The asphalt cools quickly and is soon ready for application of the cover. For canal velocities below about 1½ft per second, the soil removed from the canal in over-excavation furnishing and applying the asphalt, and all cover operations. The actual cost of a particular scheme is influenced by problems of subgrade preparation peculiar to the site, the rate of application in gallons per square yard, the cover requirements, and weather conditions.

Hot-sprayed asphalt linings are not suited to small rehabilitation and maintenance schemes. For these and other projects where simpler installation is desired, prefabricated linings have been developed that do not involve the handling of hot materials and can be applied by inexperienced workmen using simple equipment. Such linings are designed to be handled and placed in much the same manner as rolled roofing, with lapped and cemented joints. To protect and retain the prefabricated membrane, it must be covered with earth or gravel in the same manner as the hot-placed membrane. Although a prefabricated lining which may be used without cover material has been given consideration, development of this idea has been unsuccessful. Early prefabricated linings utilised reinforcements of canvas, jute, sisal or asbestos sheets. These linings were high in cost and, in addition,



Travelling Plant Mixer Used with Mobile Form

may be used, provided it is of reasonable stability. In canals with high velocities, the earth cover is often protected by a pit-run gravel blanket 3in to 6in thick. Riprap is frequently used where turbulence is severe. Experience indicates that the life of a buried asphalt membrane lining is largely dependent on the maintenance of the cover over the membrane.

The first installation of buried asphalt membrane lining by the Bureau of Reclamation, involving only 1155 square yards, was placed on the Klamath project in Oregon, in 1948. This section was lined with several asphaltic materials, including emulsified asphalt, air-blown asphalt and catalytically blown asphalt. The marked superiority of catalytically blown material in these tests led to its adoption for all buried membrane linings. The cover soil was placed to a depth of 1ft. On the basis of the satisfactory results obtained with the Klamath lining, three larger experimental installations of buried asphalt membrane linings were placed early in 1949 on the Shoshone, Riverton, and Kendrick projects in Wyoming.

Since these experimental installations, buried asphalt membrane has gained wide use as a rapid, low-cost method of controlling seepage. Some 1,750,000 square yards of buried asphalt membrane lining, covering nearly 80 miles of canal, have now been placed by the Bureau of Reclamation. Costs of contract installations have ranged from 82 cents to 1·71 dollars per square yard, including preparation of subgrade, were heavy and bulky, making transport over long distances impractical and placing costs excessive. Two prefabricated asphalt membrane linings which show considerable promise have been used in a number of experimental installations. One of these employs a heavy kraft paper upon which a $\frac{1}{16}$in coating of catalytically blown asphalt is applied. The paper, costing less than a cent per square yard. serves only as a temporary reinforcement during manufacturing, transport and placing, and then disintegrates rapidly, leaving an unreinforced asphalt membrane of uniform thickness. The lining is fabricated in strips 3ft wide and 36ft long, supplied in rolls, and placed on the over-excavated subgrade either transversely or longitudinally. Joints are lapped 2in and cemented with cut-back asphalt. The second type of prefabricated material is reinforced with a thin mat of glass fibres to form the same size strips, but only ¼in thick. This material is lighter in weight (about 6 lb per square yard as compared to 11 lb for the paper-backed material), and is therefore cheaper to transport. The fibre-glass reinforcement increases the strength, which is an advantage in placing, but it also increases the cost. The lapped joints are sealed and cover is applied in the same manner as for the paper-backed material.

The first experimental installation of the paper-backed prefabricated membrane was in a 690ft length of lateral of the Klamath project. Approximately 3500 square yards of the lining were placed. A variety of materials were tried

for sealing the joints, including asphalt emulsion, kerosene, and other light oils, but cut-back asphalt proved best. Long wire pins pushed through the membrane into the subgrade satisfactorily held it in place on the side slopes until it could be covered. When placing temperatures fell below 45 deg. Fah., warming of the rolled membrane to about 60 deg. Fah. was found necessary to avoid cracking of the asphalt. Material for this project was manufactured in California at 30 cents per square yard. The cost of the entire lining installation, including the material, preparation of the subgrade and cover, was 76 cents per square yard.

The fibre-glass reinforced prefabricated membrane was first placed in a small lateral of the W. C. Austin project in Oklahoma, where seepage measurements were taken before and after lining. Losses through the subgrade before lining were in excess of 1 cubic foot per square foot of wetted area per twenty-four hours, and less than 0·10 cubic foot after lining. The cost of the entire installation was 1·50 dollars per square yard.

Earth-Material Linings

Canal linings of natural or processed soils have often proved economical for the reduction of seepage and the stabilisation of banks. Impervious soils of a wide variety have been employed in the construction of either thin or heavy compacted earth linings. Thin compacted earth linings of the Bureau ordinarily contain a 6in to 12in layer of thoroughly compacted impervious soil protected by a 6in to 12in cover of coarse soil or gravel. However, the cover and lining thickness requirements vary with the type of soil used, the velocity of the water to be conveyed, and other project conditions. Thus, gravel with excess clay might well be used without cover to resist erosion. Soil types which are generally considered to be suitable for use in thin compacted linings include : (1) sand with clay binder, (2) sand with excess clay, (3) gravel with excess clay, (4) lean clay, and (5) fat clay. Fat clays are not suitable for lining canals which are subject to alternate wetting and drying unless the lining is protected by a gravel-sand cover. Prior to the use of a selected soil for lining, its maximum density, optimum moisture and permeability is determined in the laboratory. Bureau construction specifications usually require an emplacement density equal to 95 per cent of the laboratory maximum. Compaction of thin earth linings is generally accomplished with sheepsfoot rollers, although other equipment has been satisfactorily used. One method used for compaction is to pull the rollers up and down the slope with a dragline or some other equipment operating from the bank of the canal. However, the operation of the compaction equipment lengthwise along the canal, with the rollers fastened to some heavy mobile equipment moving along the bank when compacting the side slopes, has been found to be more satisfactory.

Thin compacted earth linings have not been widely used on Bureau projects, probably due to the relatively high cost of side slope compaction and the danger of removal by scour or in canal cleaning. On the Boise project in Idaho approximately 23,000 square yards of 12in compacted earth lining were placed in the Black Canyon Canal at a cost of about 17 cents per square yard. In the "D" Line Canal on the same project 4750 square yards of 18in lining were placed at a cost of about 37 cents per square yard.

With the development in recent years of construction equipment capable of handling economically large quantities of earth, the heavy earth canal lining has become very attractive and low in cost for medium and large-sized canals. In this type of lining, the bottom and side slopes are built with selected impervious soils compacted in horizontal layers 6in thick. The bottom thickness on Bureau installations is usually 2ft, but varies with the requirements of the scheme. The layers on the side slopes are usually 6ft to 8ft wide, and can accommodate conventional large earth-moving and compaction equipment. The actual thickness of the lining on the side slopes is about 3ft, measured perpendicularly to the slopes. Because of the high uniform density, stability and thickness of this type of lining, no protective cover is required except at curves and other points of high velocity. Materials adaptable for use in heavy compacted earth linings include those listed above as being suitable for thin compacted linings and, in addition, gravel with sand-clay binder and gravel with an excess amount of silt. In general, the soils best suited for use in heavy compacted earth linings are gravels and sands with clay binder and gravel-sand-clay mixtures because of their low permeability, high stability and good resistance to erosion. Since conventional large earth-moving and compaction equipment is adaptable to this method of lining, low costs can be realised if the volume of earth to be moved is large and suitable soils are available within reasonable hauling distances. In 1944, a 300ft section of the Conchas Canal in New Mexico was lined with heavy compacted earth at a cost of 1 dollar per square yard of lining. Much lower contract costs, ranging from 42 cents to 46 cents per square yard of lined surface, were realised on 18 miles of the Delta-Mendota Canal and on 25 miles of the Friant-Kern Canal of the Central Valley project in California.

A properly constructed heavy compacted earth lining has been found by actual field tests to be highly impermeable, with water losses in the order of 0·07 cubic foot per square foot of wetted area per twenty-four hours. This loss is comparable to that of a good concrete lining. In areas where expansive soils or high ground water predominate, heavy compacted earth lining may actually be preferable to concrete lining. Rigid concrete linings have been ruptured by the expansion on wetting of expansive subgrade soils or hydrostatic pressures from high ground water, whereas earth linings, which are characterised by a greater weight and flexibility, are not damaged by these forces.

Loosely placed earth linings consist of an uncompacted blanket of selected fine-grained soil dumped in the canal and spread over the bottom and side slopes to an approximate line and grade in layers about 12in in thickness. The soils to be used for lining materials are required to be sufficiently fine to be impervious in a loose state and be adequately stable to resist erosion to a reasonable degree. They are tested for permeability in a loose state, and for the effects of water action on their permeability. Uncovered loose earth linings have been found to be subject to excessive erosion and severe damage from maintenance, particularly weed removal. However, rather permanent seepage control may be obtained with these linings if the underlying soil is of an open nature and contains sufficient voids to permit penetration of silt and clay particles. Loose earth linings require very little trimming or reshaping of the canal section prior to placing. Furthermore, equipment requirements for placing are exceptionally simple. As a result, the cost of this type of lining is much less than that of compacted linings. Unit costs for 12in loose earth linings in the Coachella and Yakima Ridge Canals, placed in 1944-45, were 28 cents per square yard of lined surface. A more recent installation in the Fire Mountain Canal of the Paonia project cost 36 cents per square yard for 6in of loose earth with a 6in gravel cover over areas subject to high turbulence.

Miscellaneous Linings

The search by the Bureau for a lower cost canal lining material has led to the investigation of many materials and combinations of materials. Two of these worthy of brief mention and brief discussion are "shotcrete" over an asphalt membrane, and synthetic plastics. The former type of lining consists of a thin cover of "shotcrete" applied over an asphalt membrane placed directly on the earth subgrade. The rather unusual combination of materials developed from the need for a stable, erosion-resistant cover for an asphalt membrane. This lining, being relatively thin, shows promise for special use in areas of rock cut where low-cost seepage control is needed, but where over-excavation for a foot or greater depth of earth cover is not feasible. The requirements for subgrade preparation are, in general, the same as for the buried asphalt membrane lining, previously discussed. Either hot, catalytically blown asphalt or prefabricated asphalt membrane may be used, the application being made in the same manner as described for the buried membrane lining. It was found advisable from early laboratory and outdoor tests to apply a tack coat of asphalt cutback to the prefabricated asphalt membrane just prior to the application of the "shotcrete" for the purpose of obtaining better bond between the two materials. The "shotcrete" cover, nominally ¾in thick, is of the same quality and mix as required for regular "shotcrete" canal lining. Since the thickness of "shotcrete" is less than ordinarily employed, extra care is necessary in controlling and checking the thickness.

Two field test installations of shotcrete over asphalt membrane have been placed on the Orland and Riverton projects in California and Wyoming, respectively. About 2000 square yards involving both hot-applied and prefabricated membrane, were placed on the Orland project in December, 1950, and January, 1951. This installation was handicapped by bad weather during construction, and subsequently by hydrostatic pressures from unusually high ground water. The contract costs averaged 2·17 dollars and 3·04 dollars per square yard for the hot-applied and prefabricated membranes, respectively, with shotcrete cover. The subgrade preparation was made by Government forces and, because of unstable conditions in the subgrade, mechanised equipment could not be used. Because of the high ground-water level, several breaks occurred in the bottom of this lining before it was put in service, but the side slopes and much of the bottom were undamaged. A total of approximately 4300 square yards of this lining was placed by Government forces in laterals of the Wyoming Canal on the Riverton project, in April, 1951. Here subgrade conditions were satisfactory and all the membrane was hot-applied. The subgrade and lining costs were 3·91 dollars per square yard.

Canal linings of synthetic plastic have been under consideration by the Bureau of Reclamation and by a number of manufacturers for some time. The main advantage of this type of canal lining is the low weight per unit area, permitting transport of lining material over long distances without excessive charges. Recent improvements and increased availability of raw materials have resulted in greater quantities of plastics being made available at relatively low cost. One of the most promising plastic compositions is polyethylene, which is rolled into sheets from 1ft to 5ft in width and from 0·001in to 0·010in in thickness, with a thickness of 0·002in appearing to be most applicable to canal linings. The present applications of this type of lining are confined to small experimental installations where the behaviour of the plastic material under simulated job conditions is being investigated. Preliminary tests indicate that the plastic lining has not only a high resistance to rupture over a rough subgrade, but also high resistance to rot. Successful use of plastic sheet will depend upon developing a suitable cover to hold it in place. Nothing will bond permanently to it and earth or gravel covers require very flat slopes.

Standardisation of Canal Sections

The recent development of mechanical lining equipment for placing hard-surface linings has made it evident that maximum economy and benefits can be realised only if canal cross sections are standardised. The problem of standardisation of lined canals has been given considerable study by the Bureau and, as a result, standard sections have been developed for use where hard-surfaced linings such as Portland cement or asphaltic concrete are to be constructed. The Bureau of Reclamation has felt that the need for and the possible benefits of the standardisation of canal sections is greatest in the smaller canals not exceeding 6ft in base width, the design of the larger canals being necessarily an individual problem. The several widths and the depth increments of the standard sizes represent a total of twenty different cross sections for the smaller canals, from which the section and the canal gradient within the range permitted by the topography may be selected, that will carry the required flow most efficiently.

Titanium: A Survey

By P. L. TEED,* A.R.S.M., F.R.Ae.S.

No. I

In this abstract from a lecture before the Royal Aeronautical Society, on January 29, 1953, the author discusses the involved processes of producing titanium and its very high cost. Following an analysis of the physical and engineering characteristics of pure and commercially pure titanium it is concluded that any metallurgical potentialities depend largely on alloying, and its alloys with metals, gaseous elements and non-metallic solids are examined. After mentioning some forging disadvantages the remainder of the article is concerned with the fatigue, notch fatigue, impact, creep and damping properties of these alloys.

TITANIUM, unlike the metals first known to man, such as gold, silver, mercury, copper and iron, is not found in the elemental state. At a later stage, when the chemistry of the metal is touched upon, it will be appreciated how this comes about. It might, however, be mentioned that, at temperatures existing when the world was very young, its chemical affinity for other elements, which over a century and a half ago so greatly impressed Klaproth, made impossible its existence in an uncombined stage.

TABLE I.—*Some Metallic Constituents of the Earth's Crust, Parts Per Million*

(*Principles of Geochemistry*, Brian Mason, Chapman and Hall, 1952.)

Aluminium	81,300
Iron	50,000
Calcium	36,300
Sodium	28,300
Potassium	25,900
Magnesium	20,900
Titanium	4,400
Manganese	1,000
Rubidium	310
Strontium	300
Chromium	200
Nickel	80
Copper	70
Tin	40
Lead	16
Uranium	4
Silver	0·1

Although, as will have been seen from Table I, the world is by no means poor in titanium minerals, it has to be admitted that at present the metal is rare indeed and well beyond the price that can be legitimately paid for most engineering purposes for which, on the basis of its density, mechanical properties and relative freedom from corrosion, it might otherwise be advantageously employed. This combination of abundance of raw materials and scarcity of the metal they contain largely arises from that very quality of titanium which so struck Klaproth—its all-too-stubborn reluctance to be reduced to the metallic state.

In the century and a half which has elapsed since Gregor's initial discovery of the element, only two practical processes for its production in ductile form have been evolved. One, the Van Arkel, while yielding the purer end product, is so much more costly in its operation that it seems unlikely that it will be employed except for making metal on a laboratory scale for laboratory purposes. The other, the Kroll, has virtually produced the whole of the titanium so far used for engineering purposes.

The Kroll process is extremely simple in conception, but its operation on a scale to produce titanium in such quantities as would be of significance to the aircraft industry, involves chemical engineering problems of the utmost difficulty and complexity.

Like that of Hunter of thirty years earlier, it consists of reducing titanium tetrachloride by means of a chemically more active metal. While Hunter employed metallic sodium, Kroll used and continues to use magnesium. Both, under the conditions in which they operated their respective methods, were left with titanium in powder form, mixed with several times its weight of the chloride of the metal used for the reduction of the original titanium salt.

The chemistry of Kroll's process is shown in the following equation :—

$$\underset{\text{Titanium tetrachloride}}{TiCl_4} + \underset{\text{Magnesium}}{2Mg} = \underset{\text{Titanium}}{Ti} + \underset{\text{Magnesium chloride}}{2MgCl_2} \quad . \quad . \quad (1)$$

Or, expressing this differently, 190 parts by weight of titanium tetrachloride, reacting with forty-eight parts of metallic magnesium, produce forty-eight of metallic titanium and 190 of magnesium chloride ; or, put in yet another way, to produce a pound of titanium theoretically requires a pound of magnesium. In practice, about 1¼ lb are employed. This indicates to the engineer that titanium, so long as it is made by this process, cannot be cheap—the present American price of magnesium ingot is 24·5 cents per pound, that of titanium sponge is 500. These figures are impressive rather than satisfactory. Neither magnesium ingot nor titanium sponge are engineering materials. Their relative prices, therefore, are of no real concern to the engineer. At a later stage some comparison is made on a basis involving both cost and mechanical properties of sheets of current titanium, aluminium and magnesium alloys. This puts the price question in better perspective, but in a somewhat worse light.

Before dealing with the intricate techniques which have to be employed to convert titanium sponge into a coherent mass of metal suitable for such metallurgical operations as rolling, drawing, forging, something should be said of the production of titanium tetrachloride.

The chemistry involved is expressed by the following equation :—

$$\underset{\text{Titanium dioxide}}{TiO_2} + \underset{\text{Carbon}}{2C} + \underset{\text{Chlorine}}{2Cl_2} = \underset{\text{Titanium tetrachloride}}{TiCl_4} + \underset{\text{Carbon monoxide}}{2CO} \quad . \quad . \quad (2)$$

Although this gives the impression of being simple, it is a complex operation, the intricacy of which is broadly indicated by pointing out that while Ilmenite concentrates containing 45 per cent titanium dioxide can be bought for £10 per ton (which is something like £37 a ton for metallic titanium in this form) titanium in the form of pure titanium tetrachloride costs at least £500 a ton of titanium.

The perplexities involved in converting titanium tetrachloride into titanium sponge require some review of the chemistry and physics of both the substances taking part in the reaction, and also of the plant in which this is carried out as a commercial operation.

Titanium Tetrachloride ($TiCl_4$).—This substance, at normal temperature and pressure, is a liquid having the following physical characteristics :—

Density at 15 deg. Cent.	1·76
Melting point	−25 deg. Cent.
Boiling point (at normal pressure)	136 deg. Cent.

It is decomposed by water and by aqueous vapour, which accounts for its use as a material for the production of smoke screens.

Magnesium.—This metal possesses the following properties :—

Density at 15 deg. Cent.	1·74
Melting point	651 deg. Cent.
Boiling point (at normal pressure)	1120 deg. Cent.

Titanium.—This metal has the following characteristics :—

Density at 15 deg. Cent.	4·5
Melting point	1725 deg. Cent.
Boiling point	Not determined

Anhydrous Magnesium Chloride ($MgCl_2$).—This substance is extremely hygroscopic. It forms with water, hydrated salts which decompose on heating into magnesia and hydrochloric acid. In its anhydrous form it has the following properties :—

Density at 15 deg. Cent.	2·32
Melting point	708 deg. Cent.
Boiling point	1412 deg. Cent.

These differences in physical characteristics indicate some of the difficulties which have to be taken into consideration in bringing about the reaction indicated in equation (1). It is, however, the respective chemical properties of the different substances and the extreme sensitivity of titanium to traces of oxgyen and nitrogen which make this problem of such formidable dimensions. Both titanium tetrachloride and anhydrous magnesium chloride react with aqueous vapour. Metallic magnesium, if molten, must be out of all contact with oxygen or water vapour. Similarly, since metallic titanium under the conditions of temperature required by the Kroll reaction will combine with all gases except those of the inert series, the decomposition of titanium tetrachloride must be done either under greatly reduced pressure or, in an atmosphere

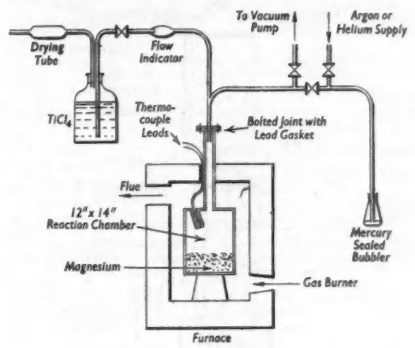


Fig. 1 : Diagrammatic Sketch of Apparatus Used for Production of 15 lb Runs of Titanium Sponge (U.S. Bureau of Mines)

of such completely chemically inert gases as helium or argon.

Fig. 1 shows a diagram of the apparatus used by Dean and others.[1]

DEVELOPMENT OF THE KROLL PROCESS

The Kroll process of 1946, however great admiration may be for its technical ingenuity, cannot have failed to impress adversely anyone addicted to economic thinking. In its then state of development it was not merely a batch process, but one which involved a number of difficult and different operations, each of which had to be done on a batch basis.

A reaction chamber had to be prepared for each charge. This involved two operations—the chamber had to be closed by means of welding and, after waiting long enough for the contents to cool to atmospheric temperature, the chamber had to be opened by cutting. This led to the loss of the residual heat of both charge and chamber.

The standard way of removing the products of the reaction (roughly one part by volume of titanium sponge mingled with eight parts of anhydrous magnesium chloride) by boring out with a machine tool, is impressive in its crudity. The chips from this last operation had to be chemically treated in a batch in order to separate the magnesium chloride and leave the titanium as a number of detached particles. These had then to be magnetically treated to remove iron. Finally, the batch application of a powder metallurgy technique involving, *inter alia*, heating this sponge for long hours, at a high temperature, in a high vacuum, had to be employed. This gave rise to metal which had to be forged in order to turn it into an engineering material.

The first simplification which has taken place concerns the treatment of the products of the reduction process. Their mechanical boring out and subsequent chemical treatment to remove the anhydrous magnesium chloride, has largely been abandoned. When the reaction is complete and the chamber is about 800 deg. Cent., time is given for the sponge, anhydrous magnesium chloride and unreacted metallic magnesium to separate under the influence of gravity. While still fluid, these are tapped off. This done, the contents of the hot chamber, now mainly titanium sponge, are subjected to a high vacuum under the influence of which the remaining magnesium chloride and magnesium are distilled off. Then, as argon is admitted, the chamber is allowed to cool to atmospheric temperature and pressure, when it is opened, the sponge removed and arc or induction melted to form ingots.

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Probably by such means the bulk of the titanium now available has been produced, but given enough clever metallurgical engineering there is no reason to doubt that the Kroll process will cease to be a batch one. Its reaction chamber will be fed in stoichiometric quantities and without intermission with molten magnesium and liquid titanium tetrachloride. It will discharge continuously the products of their reaction into an electric arc furnace in which the freshly

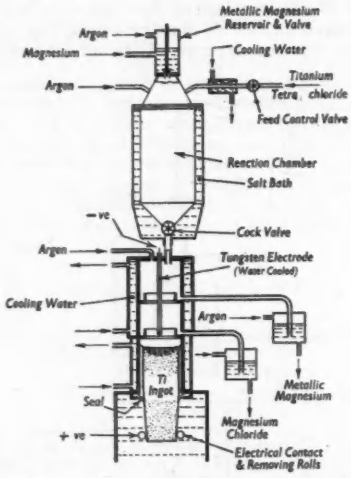


Fig. 2—Sketch of Plant for the Continuous Production of Titanium Ingots

created particles of titanium will be melted into a coherent whole. The resulting anhydrous magnesium chloride and any unacted upon magnesium will be distilled off and condensed. The former will be used for electrolytic re-reduction to the metallic state, while the unacted upon magnesium will be merely returned to the molten magnesium tank from whence, ultimately, it will go back to the reaction chamber.

Such a scheme as this has been considered by Maddex and Eastwood.[2] Their ideas were sponsored by U.S. Air Material Command, Wright-Patterson Air Force Base, Dayton (Contract No. W33-038, ac-21229). They have largely been tried out and have had such a measure of success as to make reasonably certain that their aim will be reached ultimately. Fig. 1 showed a diagrammatic picture of the Kroll process as it was ; Fig. 2 shows what it is on the way to becoming.

Above the reaction chamber is a vessel containing metallic magnesium at a temperature of 760 deg. Cent., that is at about 110 deg. Cent. above its melting point. The pressure head in this part of the unit has to be kept constant by the controlled pumping of molten magnesium from a holding furnace, kept at the appropriate temperature. This operation is not novel. For a number of years now the Dow Chemical Company have been transferring liquid magnesium at constant rate by means of mechanical pumps.

From this cistern of liquid magnesium, the metal runs into the reaction chamber. Here it meets the titanium tetrachloride. This is fed in at the rate appropriate for the carrying out of the reaction set out in equation (1). The technical requirements of this chamber are such that reaction is complete when the products of it, solid particles of metallic titanium and liquid ones of anhydrous magnesium chloride, reach its conical bottom, from where they flow through a valve to the next part of the unit.

It will be apparent that the dimensions of this reaction chamber are of great importance. They must be closely related to the speed of chemical reaction and to show how difficult it is to give practical effect to this, it should be pointed out that this is influenced both by pressure and temperature. It therefore follows that both these must be kept constant during the operation of the plant. Pressure presents no difficulty ; the chamber has merely to be in direct communication with a vessel containing an inert gas, such as argon, which is at an appropriate pressure. Maddex and Eastwood[2] consider this to be 2 lb to 3 lb per square inch above that of the atmosphere. The maintenance of a suitable temperature is more difficult, for the reaction between metallic magnesium and titanium tetrachloride is exothermic. In order to secure as uniform a thermal condition throughout the whole as is possible, Maddex and Eastwood advocate its immersion in a salt bath kept at a steady temperature somewhere between 732 deg. and 871 deg. Cent.

The next portion of the unit is an arc furnace, the design of which presents very great difficulties indeed, for it has to perform a four-fold function. Not only has it to melt the particles of titanium (melting point 1725 deg. Cent.) so that they run together and may be subsequently continuously cast into an ingot ; it has to distil from the mixture which runs into it from the reaction chamber, the anhydrous magnesium chloride and any unreacted metallic magnesium. These two have to be subsequently and separately condensed and; in liquid form, returned to the appropriate parts of the unit. Thus, this arc furnace is not merely a melting one. It is a continuous casting machine and is also a fractionating still, volatilising and separating two substances, anhydrous magnesium chloride (boiling point 1412 deg. Cent. and melting point 708 deg. Cent.) and metallic magnesium (boiling point 1120 deg. Cent. and melting point 651 deg. Cent.).

It is not impossible that a continuous process will be evolved in which the input will be almost limited to titanium dioxide, coke and electrical energy. Anyone, unfamiliar with metallurgy, but knowing the mechanical engineering triumphs of the aircraft industry, may, at this stage, feel that the development of the Kroll process gives promise of titanium becoming available in the near future at a price which would not prohibit its employment for general engineering purposes. The metallurgist, on the other hand, may doubt if this is within the ambit of its potentialities. These facts will be in his mind—to produce a ton of titanium requires a ton and a quarter of metallic magnesium, costing in the United Kingdom about £400 (and what, as far as the United Kingdom is concerned is more important, consuming about 25,000kWh in its manufacture.[3]) Further, he will recall that titanium tetrachloride, long an article of commerce, is not yet inexpensive, and, finally, he will hazard that owing to the inherent chemistry and physics of titanium itself, its production in such forms as the engineer may require is likely to be costly in the extreme. These contrasting views will receive further consideration.

The approximate cost per ton of titanium metal in various forms is given in Table II :

TABLE II.—*Approximate Cost *of Metallic Titanium Per Ton in Various Forms*

Material	Cost in pounds sterling of 1 ton of titanium
Ilmenite concentrate (45 per cent TiO_2)	£37
Titanium tetrachloride	£500-£600
Titanium sponge	£4,000
Bars, hot-rolled	£7,900
Forgings, rounds, discs, &c.	£7,900
Sheet and strip	£11,900

* The cost of metallic titanium in this Table has been based on current American prices converted on the basis of $2·82/£1 sterling.

About a century ago, aluminium, now the aircraft industry's predominant metal, was sold by the pound at a price equivalent to £125,000 a ton. To-day, it can be bought by the 1000 tons for £167 a ton, a change brought about by invention and the exploitation of invention, both of which may well make a powerful contribution to the development of a titanium industry.

Whether or not titanium and its alloys are justifiably usable by the aircraft engineer depends on two considerations—what can this metal do which cannot be done by cheaper means, and what is the monetary value of this achievement ?

As this story unfolds, some means of increasing the disposable load of aircraft will be indicated, but what the purchaser is prepared to pay for this must determine the issue.

The military authorities have, rightly, a method of evaluation depending on contemporary exigencies, but this is not so for civil airlines. Through the courtesy of Mr. Peter Masefield, the author is able to give the following figures of gross revenue per annum derived per pound of disposable load of the following aircraft :—

Aircraft class	Gross revenue in pounds sterling per pound of disposable load
D.C.3	12 (actual)
"Viking" (first-class)	29 (actual)
"Elizabethan" (first-class)	49 (estimated)

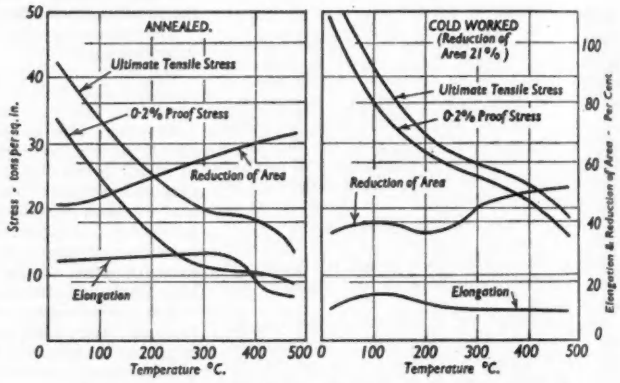
These figures should be borne in mind when consideration is given to Table VIII.

Finally, because of two characteristics of titanium, its high melting point (1725 deg. Cent.) and its intense chemical activity when molten, its scrap cannot be remelted and used again for making fresh wrought material.

Pure and Commercially Pure Titanium as an Engineering Material

On the basis of Table III it can be said that titanium is virtually a non-magnetic metal of high melting point, having a coefficient of expansion comparable with that of steel, an electrical conductivity of about 3·2 per cent that of conductivity grade copper, and a thermal conductivity which is of about the same order. Its density is about 57 per cent of that of steel and 1·7 times that of aluminium, while its Young's modulus is about half that of iron, and one and a half times that of aluminium.

From the aircraft industry's point of view, at atmospheric temperature titanium is entirely



Approximate chemical composition :—Carbon, 0·31 per cent ; nitrogen, 0·002 per cent ; oxygen, not determined ; manganese, 0·07 per cent.

Fig. 3—Tensile Properties at Elevated Temperatures of Arc-Melted Commercial Purity Titanium

free from corrosion troubles. In chemical engineering it already has application and later may well have wide ones in this field.

In the molten state, titanium is intensely chemically active. It combines violently with all gases other than those of the monatomic series such as helium and argon. This demands that the metal must be melted and cast in an atmosphere of the kind indicated, or else *in vacuo*.

TABLE III.—*Physical Characteristics of Pure Titanium, i.e. Better than 99·9 per cent. Ti*

Atomic number	22
Atomic weight	47·9
Crystalline structure :	
Up to 885 deg. Cent. ...	Close-packed hexagonal
Above 885 deg. Cent. ...	Body-centred cubic
Atomic spacing :	
Up to 885 deg. Cent. ...	a=2·950 A deg.
	c=4·683 A deg.
Above 885 deg. Cent. ...	a=3·31 A deg.
	c=3·31 A deg.
Coefficient of linear expansion	15–730 deg. Cent., $8·8–9·2 \times 10^{-6}$ per deg. Cent.
Thermal conductivity	0·036 calories/cm²/cm/sec/ deg. Cent.
Specific heat	0·13
Electrical resistance, microhm/cm/cm³	60
Density, gm/c.c.	4·507
Melting point	1725 deg. Cent.
Young's modulus, lb/in² ...	15×10^6

There is no material, metallic or non-metallic, out of which moulds can be made with which

liquid titanium (i.e. above 1725 deg. Cent.) will not react disastrously.

Engineering Characteristics.—The foregoing brief description does not contain much to attract and it omits much of significance. Except for the metal's elasticity, density and, at atmospheric temperature, chemical inactivity, no qualities have been mentioned which are of particular interest either to the aircraft structural or mechanical engineer. In the form of annealed sheet, strip, bars, forgings, and so on, the commercially pure titanium can now be expected to have at least the mechanical properties given in Table IV.

TABLE IV.—*Mechanical Properties of Commercially Pure Titanium*

Property	
0·2 per cent proof stress	33·5 tons/sq in
Ultimate tensile stress	39·0 tons/sq in
Elongation	23 per cent

This metal would cost approximately the following prices :—

Sheet, strip	£11,900 per ton
Bars, forgings, &c.	£7,900 per ton

On the rigidity/weight basis, titanium and titanium alloys at atmospheric temperature have a somewhat lower specific rigidity than the older structural alloys.

TABLE V.—*Specific Rigidity of Four Aircraft Materials*

Material	Young's modulus lb/in²/10⁻⁶	Specific gravity	Specific rigidity 10⁻⁶
Commercial grade titanium (annealed)	15	4·5	3·3
Aluminium alloy 75S ...	10	2·9	3·5
Magnesium alloy FS1 ...	6·5	1·8	3·6
Nickel chromium steel, B.S. S.99	29	7·8	3·7

While the elastic moduli of titanium can be appreciably raised by allowing (admittedly at the sacrifice of some desirable qualities), it appears improbable, even with a reduction in price, that the metal will be extensively used for the main structure of even high-speed aircraft. This view was recently endorsed by Sir Ben Lockspeiser.[4]

FORGINGS

The airframes of contemporary machines are not without some massive forgings. Some are made in alloy steel, but more are of such aluminium alloys as D.T.D.364 and 683. Since, in general, their form is such that questions of rigidity do not arise, it is the 0·1 per cent proof stress of the material which will provide the design criterion. On the basis of this and of current prices for forging bars made of the three selected alloys, the figures in Table VI give the relative price of the material in the forgings :

TABLE VI.—*Relative Cost of the Material in Forgings of Equal Strength*

Material	0·1 per cent proof stress, tons/sq in	Density in lb/sq in	Cost/lb, shillings	Relative cost
Commercial grade titanium	32	0·16	70·5	57·7
Aluminium alloy D.T.D. 683	27	0·101	3·3	2·0
Nickel - chromium steel, B.S. S.99	70	0·283	1·5	1·0

Nothing has yet been said about the use of commercial grade metal in the airframes of supersonic aircraft. This omission is intentional. Somewhat surprisingly in view of its high melting point, unalloyed annealed titanium has disappointing creep characteristics, even at room temperature,[5, 15]. Fig. 3, based on work by Lee Williams,[6] shows the variation with temperature of annealed and cold worked material as regards its static mechanical properties. The creep properties of the cold worked metal, however, are much better than those it possesses in the annealed state.

Finally, in military aircraft, there is reason to suppose that the grade of titanium under consideration may prove effective as armour, on a weight basis, for it can be surface-hardened by a number of methods which have yet to be tested realistically. The metallurgical potentialities of the metal depend largely on alloying.

REFERENCES

[1] Dean, R. S., Long, J. R., Wartman, F. S., and Anderson, E. L. (1946) : "Preparation and Properties of Ductile Titanium," American Institute of Mining and Metallurgical Engineers. *Tech. Pub.* 1961, 1946.

[2] Maddex, P. J., and Eastwood, L. W. (1950) : "Continuous Method of Producing Ductile Titanium," *Journal of Metals*, April, 1950.

[3] Teed, P. L. (1946) : "Anglo-American Magnesium Production," *Trans. Inst. Mining and Metallurgy*, Vol. 56, 1946.

[4] Lockspeiser, Sir B. (1952) : "Progress in Aeronautical Science and Engineering," Presidential Address, Section G, British Association, 1952.

[5] Adenstedt, H. (1949) : "Creep of Titanium at Room Temperature," *Metal Progress*, 56 (5), November, 1949. See also *Handbook on Titanium Metals*, sixth edition, page 33, Titanium Metals Corporation.

[6] Lee Williams, W. (1951) : "How Titanium Behaves at Temperatures up to 900 deg. Fah.," *The Iron Age*, June 14, 1951.

[7] Hansen, M. (1936), *Der Aufbau der Zweistoffleglerungen*, J. Springer, Berlin, 1936.

[8] Craighead, C. M., Simmons, O. W., and Eastwood, L. W. (1950) : "Titanium-Binary Alloys," *Journal of Metals*, March, 1950.

[9] Jenkins, A. E. and Worner, H. W. (1951) : "The Structure and Some Properties of Titanium-Oxygen Alloys Containing 0·5 Per Cent Oxygen," *Journal Inst. Metals*, Vol. 80, Part 4, 1951–52

[10] Voldrich, C. B. (1952) : "The Welding of Titanium Alloys," Adams Lecture, American Welding Society, October, 1952.

[11] Brown, D. I. (1952) : "Titanium, Our No. 1 Problem Metal," *The Iron Age*, October 2, 1952.

[12] Hanink, H. H. (1952) : "Application of Titanium to Aircraft Engines," S.A.E. National Aeronautic Meeting, New York, April 21, 1952.

[13] Found, G. H. (1951) : "Increasing Endurance of Magnesium Castings by Surface Work," *Metal Progress*, August, 1951.

[14] "Titanium," a special Product Engineering Report, November, 1949.

[15] See Fig. 9 of this paper founded on information derived from *Technical Information on Titanium Metal*, Rem-Cru Titanium, Inc., Midland, Pennsylvania.

(*To be continued*)

Continuous Recording of the Effective Diameter of Screw Gauges*

By P. W. HARRISON, B.Sc. (Eng.), A.M.I.Mech.E., and Mrs. J. G. WOOD, B.Sc. (Eng.)

The machine described enables the variation in effective diameter of a screw plug gauge to be recorded graphically along the whole length of helix at a magnification of 1000 *times. It can be used for charting the sizes of batches of gauges of the same nominal form and diameter, by comparison with a master gauge of known size, to an overall accuracy rather better than* ±0·00015*in* (0·004*mm*). *A modified version of the apparatus records the variation in the effective diameter of a screw ring gauge.*

MEASUREMENT of the effective diameter of screw plug gauges is necessary, both during manufacture and at intervals during their subsequent use in the inspection of screwed work, to ensure that they conform with the specified size or have not worn below the lower limit. The measuring machine described in this paper produces a continuous record of the simple effective diameter over the full length of helix ; this represents an advance over present methods, which provides an incomplete picture, due to the limited number of positions at which measurements can conveniently be made. The design is linked in some respects with existing machines and some brief mention of these may be of interest. For a fuller review, however, the reader is referred to the first Sir Alfred Herbert paper presented by Mr. F. H. Rolt.†

Prior to the first world war, measurements of simple effective diameter were made using three needles in conjunction with a hand micrometer or, for greater accuracy, a Whitworth end measuring machine. During the early part of that war the floating micrometer diameter measuring machine‡ was developed at the N.P.L. to meet the greatly increased demand for rapid and accurate measurements of screw threads, and this essentially is the machine in use to-day. The measurement made is basically a comparison between a diameter of the screw plug and the diameter of a plain cylindrical standard, using a micrometer and fiducial indicator in conjunction with two cylindrical needles. Large numbers of gauges may be more speedily inspected in a modified version of the machine, introduced in 1938,§ in which the micrometer and fiducial indicator are replaced by an adjustable anvil and a measuring indicator. The effective diameter of a batch of screw plug gauges of the same nominal size may then be quickly compared with the diameter of a similar gauge which has itself been previously measured by the usual method

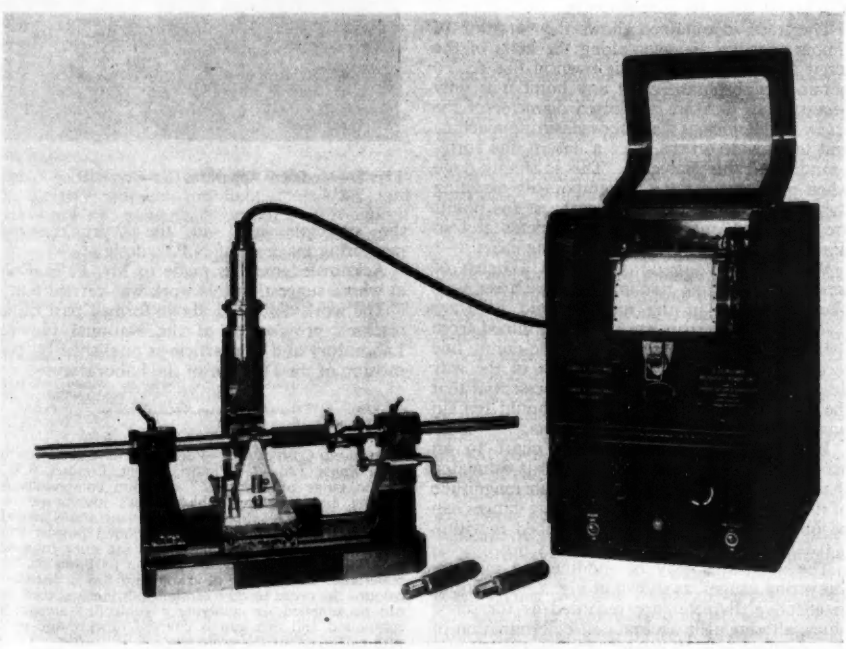


Fig. 1—Continuous Effective Diameter Machine and Recorder

* Communication from National Physical Laboratory.

† Rolt, F. H. (1952), "The Development of Engineering Metrology," *Proc. Inst. Prod. Engrs*, 1, 6.

‡ *Notes on Applied Science, No.* 1—*Gauging and Measuring Screw Threads*, page 12. Published by H.M.S.O.

§ Rolt, F. H. (1938) : "A Machine for Measuring Plug Screw Gauges in Quantities," *Machinery*, 52, 701.

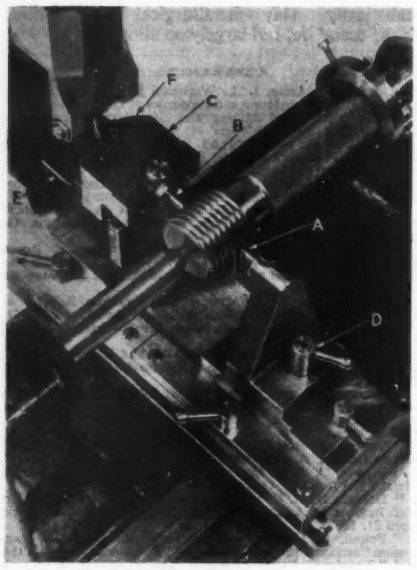


Fig. 2—Plug Gauge Mounted in Machine

the errors in effective diameter being read directly on the indicator.

The continuous effective diameter machine is also designed for rapid comparative measurements. The two needles are replaced by spherical-ended stylus points so that the plug may be freely rotated; a complete graphical record is obtained by substituting an "Electrolimit" measuring head and recorder unit in place of the indicator. The apparatus is illustrated in Figs. 1 and 2, which show a plug gauge mounted between the centres of a floating micrometer machine, and in the schematic layout, Fig. 3, which shows more clearly the basic movements. The combination of a carriage and saddle, mounted on ways mutually at right angles, provides the carriage with freedom of movement in a horizontal plane. Contact with the thread of the gauge is made through two stylus points *A* and *B* mounted on the carriage at the same height as the axis of the screw; of these, stylus *A* is rigidly supported, while stylus *B* and holder *C* are flexibly mounted on a steel strip and strut, so that the stylus is free to move

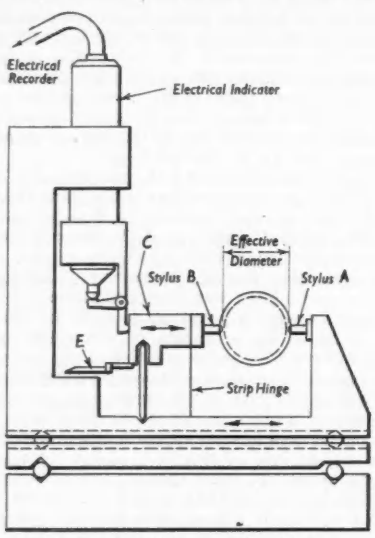


Fig. 3—Basic Movements of Machine

to a limited extent in a horizontal plane. The stylus points have spherical tips of such a radius that contact is made with the flanks of the thread in the region of the effective diameter. It is necessary that they shall be displaced relative to each other by half a pitch, and this is effected by adjusting stylus *A*, by means of control *D*, until pointer *E* coincides with a line on the carriage. In this way stylus *B* is set square to the axis of the screw. An "Electrolimit" measuring head, associated with an amplifier and recorder, is rigidly clamped to the upper floating carriage and the plunger is effectively held in contact with holder *C* by means of a bell-crank lever. Variations in effective diameter produce corresponding movements of stylus *B* with respect to the carriage, and these appear, at a magnification of 1000 times, as displacements of the recorder pen on the chart.

It is necessary to eliminate the effect of non-uniform or periodic pitch errors which may be present in the screw and which, by varying the relative displacement of the stylus points in a direction parallel to the axis of the screw, would twist the strip support. In order that this twisting movement shall not influence the "Electrolimit" head, the contact surface *F* is radiused about the vertical centre line of the strip hinge.

A small error will be introduced if damage is present at the centres of the gauge, causing it to rotate eccentrically. This is because the stylus points move away from either end of a diameter of the plug, due to its rising and falling when rotated, and effectively measure a chord displaced from the diameter by an amount which is varying. The error is, of course, more marked if the defective centre is adjacent to the threaded part of the gauge, and the gauge diameter is quite small. However, the following figures suggest that this error is not of serious consequence for values of eccentricity likely to arise in practice. Thus for a plug gauge of ½in diameter, in which the thread is rotating with an eccentricity of 0·001in, the error is rather less than 0·00002in. An error of similar magnitude would arise in measuring gauges of ¼in and 1in diameter if the thread rotated with eccentricities of 0·002in and 0·003in respectively.

Unlike the normal diameter measuring machine, the saddle as well as the upper carriage of the new machine is free to float so that, as the plug is rotated by the handle and pulley system seen in Fig. 1, the two stylus points automatically traverse the length of the helix and the corresponding variations in effective diameter are recorded. With the plug gauge dry there is a slight tendency for chatter to be set up at the stylus points. This may be overcome by coating the plug gauge with a thin film of micrometer oil, a procedure which does not introduce noticeable errors into the recorded size.

The trace so obtained shows the variation of simple effective diameter along the helix of the screw and a typical record is given in Fig. 4. To obtain the absolute size at any point it is only necessary to measure a selected diameter of the screw in the normal diameter measuring machine and to provide on the trace a datum line corresponding to this diameter. This is simply done when making the trace by temporarily arresting the motion of the screw when the stylus points are registered on the selected diameter and so drawing a straight line on the moving chart.

When it is required to measure a batch of screws of the same nominal size, each screw is placed in turn in the machine and its trace recorded. The errors are then determined from the relationship of these traces to the datum line recorded on any one of the screws in the way described above. It is, of course, essential that the setting of the solid stylus *A* should remain unaltered during these measurements.

It is possible to reproduce a chart to an accuracy within ±0·00003in, and it is estimated that the accuracy to which the absolute magnitude of the effective diameter of screw plug gauges can be obtained by the methods described is within ±0·00015in.

The apparatus may be modified to measure screw ring gauges, as shown in Fig. 5. Variations in effective diameter are recorded as for screw plugs, although the accuracy of determination of the absolute size is lower, due to the greater uncertainty in the absolute measurement of the datum diameter. Contact with the thread is effected by cranked stylus holders, which require that the load on them shall be reversed; to achieve this, holder *C* is biased by a coil spring in tension. The ring is held in a rotating head, mounted on a hollow spindle and it is centralised by means of a hollow conical attachment mounted on a shaft. The shaft enters the hollow spindle until the conical surface contacts the bevelled face of the ring, so bringing the ring concentric with the axis of rotation. The ring is clamped in this position and the attachment removed. If the bevelled face is not formed concentrically with the thread it becomes necessary

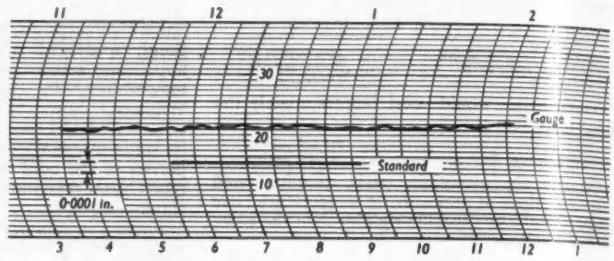


Fig. 4—Typical Record of Variation of Simple Effective Diameter

to use a more complex attachment, e.g. an expanding mandrel locating on the crests of the thread. To allow room for manipulating the conical centring attachment the traverse of the saddle was increased by replacing the three ball support by a row of equi-sized balls placed in each vee groove and held in position by a spacer.

It may be noted that the machine could be used for recording "drunkenness" of screw plug gauges, by arranging for a bell-crank lever to register on the side of block *C* and thus employing

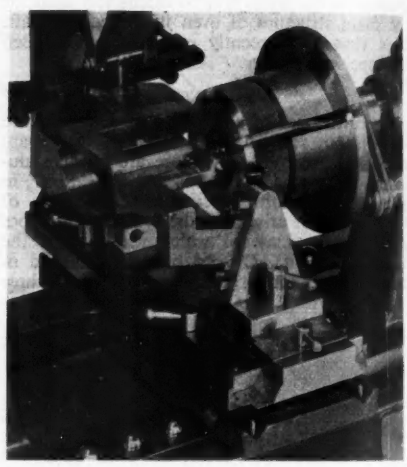


Fig. 5—Modified Apparatus for Screw Ring Gauges

the principle used in the "drunkenness" measuring machine of N.P.L. design.‖

Acknowledgment is made to Mr. F. H. Rolt, at whose suggestion this work was carried out.

The work described above formed part of the research programme of the National Physical Laboratory and this article is published by permission of the Director of the Laboratory.

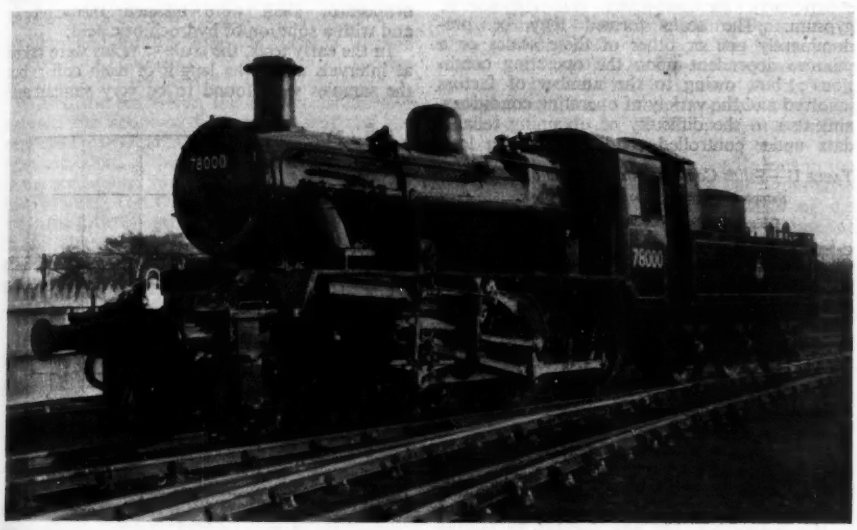
DIAMOND COMPOUNDS.—Particulars have been received from Engis, Ltd., 25, Victoria Street, London, S.W.1, of the range of "Hyprez" diamond compounds for lapping and polishing, which it has just introduced. This compound is supplied ready for use and is made in a number of forms containing diamond powder from ¼ to 90 micron grade, and suitable for work from fine metallographic polishing to roughing purposes on hard materials. Each grade of compound has a distinctive colour. In order to give economy in use a special gun can be supplied for applying a controlled amount of compound and this gun is charged quickly and easily with cartridges of the preparation.

‖ *Notes on Applied Science, No. 1—Gauging and Measuring Screw Threads*, page 20. Published by H.M.S.O.

Standard Class "2" Locomotives for British Railways

THE first of the new 2–6–0 standard class "2" mixed traffic tender engines for British Railways has been completed at the Darlington works. It is the first of ten locomotives which will be placed in service on the Western Region for duties similar to those of the "2251" and "2301" classes of the 0–6–0 classes of similar power. As with the other standard classes of locomotives, the class "2" was designed and built under the direction of Mr. R. A. Riddles, member for mechanical and electrical engineering of the Railway Executive. It is pointed out that although the new locomotive is the smallest tender engine to be built in the range of twelve for British Railways, it nevertheless incorporates, where suitable, the modern developments which have been found successful on the larger designs.

These improvements in design are intended mainly to reduce the time required at the running sheds for the preparation and disposal of the engines before they begin or after they end their journeys. Extensive use of grease lubrication with grouping of nipples into batteries has been introduced, a rocking grate is fitted, as well as a self-emptying ashpan and a self-cleaning smokebox.



2-6-0 Class "2" Locomotive

Apart from mixed traffic work the engines are particularly suitable for light main line and cross-country passenger working throughout Britain. One of the new engines is illustrated on this page and the leading dimensions are as follows :—

Cylinders, number, dia. and stroke ...	Two 16½in by 24in stroke
Wheels, coupled, dia.	5ft 0in
Wheels, pony truck, dia.	3ft 0in
Wheels, tender, dia.	3ft 3½in
Wheelbase, coupled	13ft 9in
Wheelbase, engine	22ft 3in
Wheelbase, engine and tender	44ft 1in
Heating surface :	
Tubes	924 sq ft
Firebox	101 sq ft
Total, evaporative	1025 sq ft
Superheater	134 sq ft
Grate area	17·5 sq ft
Boiler pressure	200 lb per square inch
Tractive effort	18,513 lb
Adhesive factor	4·9
Weight of engine in working order ...	49 tons 5 cwt
Weight of tender in working order ...	36 tons 17 cwt

The principal dimensions of the boiler are identical with the L.M. design of 2–6–0 class "2." The barrel consists of two rings, the second ring being tapered equally at top and bottom. The outside diameter at the front end is 4ft 3in, and at the firebox end 4ft 8in.

In the drumhead smokebox tubeplate are expanded twelve flue tubes, 5½in dia., and 162 small tubes, 1¾in dia, the length between tubeplates being 10ft 10½in. A Belpaire firebox, 5ft 11in long and 4ft $\frac{7}{16}$in wide, gives a grate area of 17·5 square feet.

The relatively large dome provided contains a vertical grid regulator which is operated from the cab by an external pull rod connected to a transverse shaft which enters the second barrel through a stuffing box. All the firebox water space stays are made of Monel metal fitted with steel nuts inside the firebox, whilst the roof longitudinal and transverse stays are of steel.

Two separate feeds are provided to the boiler, one from each of the two live steam injectors, situated below the cab on the right-hand side. Water enters the boiler through two clack valves placed at 30 deg. on each side of the vertical centre line of the first barrel. After passing through the clack valves the water passes over a tray which deflects the water to the sides of the barrel away from the tubes underneath.

Where possible, the boiler fittings are to the same standards as other B.R. locomotives. The main steam manifold is placed on the top of the firebox outside the cab and on it are mounted all the separate shut-off cocks to each steam supply pipe, a main shut-off valve operated from inside the cab being also provided. A manually operated blowdown valve is fitted for the discharge of sludge from the front of the firebox.

The main frames of carbon steel plate are 1in thick and on them are mounted the hornblocks at the driving wheel stations and the guides at the leading and trailing wheel stations. The hornblocks and guide surfaces are fitted with manganese steel liners and strips welded to a backing plate and finally bolted to the guide. Plain bearing axleboxes are fitted on the engine, those of the coupled axles having the pressed-in horseshoe brass mechanically lubricated by engine oil fed to the underkeeps in which a worsted trimmed pad feeds the oil on to the journal.

On the tender dual race outside journal roller bearing axle boxes are fitted.

Steam distribution to the two outside cylinders is controlled by piston valves of 8in nominal diameter driven by an outside Walschaerts gear, giving a valve travel of approximately 6in with $1\frac{5}{16}$in steam lap and ¼in lead. These valves are lubricated by oil delivered through atomisers from the cylinder mechanical lubricator. The pins of the valve gear are grease lubricated, except the expansion link and radius rod die pins, dies and die paths, which are oil lubricated. The bearing of the return crank rod big end is of self-aligning ball design. By adopting steam operation of the cylinder drain cocks all shafts and rods as used with mechanical operation are eliminated.

In the two-bar crossheads the top bar, which carries the load when the engine is working forward, is mechanically lubricated. The connecting-rod big-end and coupling rod bearings are lined with white metal and the oil is distributed over the bearing by a felt pad lubricated by splash feed from an oil box integral with the rod, above the bearing.

The leading pony truck has helical bearing springs, two pairs to each axlebox, each pair acting on either end of a yoke which transmits the load to the axlebox. Double helical springs are also used for the side control of the truck and two spring-loaded friction retarders are employed fore and aft of the truck centre to control further the freedom or side play of the truck.

The steam and vacuum brake equipment is identical with the other standard locomotives, and the cab is designed to suit the smaller of the B.R. loading gauges. In the cab, the layout of controls for the driver and fireman's duties follows very closely the approved mock-up which was demonstrated to motive power staff before the larger locomotives were built.

The tender has a capacity of 3000 gallons of water and 4 tons of coal, and being fitted internally for water pick-up apparatus, can be equipped externally as required. Two combined external water feed valves and sieves are fitted on each side of the tender for the water feed pipe to each injector.

The British Hydromechanics Research Report

THE fifth annual report of the British Hydromechanics Research Association, for the year ended September, 1952, was published last week. It notes that membership of the Association increased by about 15 per cent and subscriptions by about 25 per cent during the year, and that the increased income exceeded expenditure. Amongst the items noted in the research programme which have aroused considerable interest is the investigation to determine the optimum economic condition for the transport of solids in pipelines. The work is sponsored by the National Coal Board, which is primarily interested in the transport of coal, both in the pit and above ground, but it is thought that the results of the investigation will have applications in other fields such as ash handling, gravel dredging and land reclamation. The factors involved in predicting the head loss and water velocity, include the size distribution, shape, density and concentration of the material, and the diameter and slope of the pipe. An experimental rig in which varying concentrations can be circulated through a 3in experimental pipeline has accordingly been constructed to supply the missing information. In addition to obtaining data of a fundamental nature for design purposes, the Association has constructed a small-scale experimental "coal pump" for continually injecting coal into high-pressure water as an alternative to passing the coal through the pump itself. Investigations are also proceeding into transient characteristics of centrifugal pumps and flow conditions in impellers ; vortex formation and prevention in suction sumps ; hydraulic friction ; pressure surges ; seals, packings and joints ; minimum pressures in reciprocating pumps ; flow through valves at low lifts, and siphon spillways.

OIL PRODUCTION.—The Iraq Petroleum Company group reports greatly increased production in 1952, from its four associated oil fields, compared with the returns for 1951. The Kirkuk field of the Iraq Petroleum Company, Ltd., produced 15,552,715 tons, against 7,987,024 tons in 1951, and the figures for the Basrah Petroleum Company, Ltd., (Zubair field) are 2,238,177 tons, compared with 121,405 tons. Production from the Mosul Petroleum Company, Ltd., (Ain Zalah) amounted to 269,905 tons, and the Petroleum Development (Qatar), Ltd., produced 3,245,343 tons, the corresponding quantities for 1951 being 5756 and 2,332,214 tons respectively.

Scale Formation in Sea-Water Distilling Plants

By H. HILLIER, O.B.E., M.I.Mech.E.†

No. I

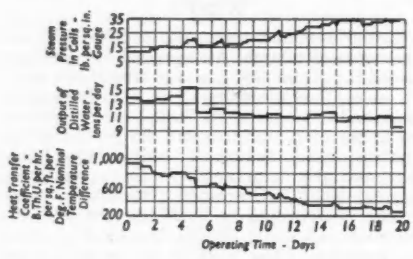
Introduction

The production of fresh water from sea water is a major requirement on naval and merchant ships, and for many communities, adjacent to the sea, in localities where the natural supply of fresh water is inadequate. In distilling plants producing fresh water from sea water, the heating and evaporation of the sea water result in a very rapid and heavy scale formation—on the heating surfaces of the evaporators in particular, and also on other heating surfaces in the distilling plant. The scale formation is cumulative in quantity and effect and offers a very serious resistance to the transfer of heat across the heating surface, so that the rate of heat transfer is seriously and progressively reduced with time of operation.

To maintain a given output of distilled water, the heating surfaces must be proportioned to allow for the scale formation. Scale formation involves frequent withdrawals of the plant from operation for its removal, so that the plant must be made larger still to obtain a required average daily output. The removal of scale is expensive and difficult and considerably increases maintenance costs. In ships, space is limited and it is desirable that the weight and space occupied by machinery for a given duty should be the minimum.

Typical Performance of an Evaporating Plant

The rate and character of the scale formed in a sea-water evaporator depend a great deal upon the operating conditions ; but the typical performance of a coil type evaporator (Fig. 1) shows


Steam Pressure in Coils - lb. per sq. in. Gauge
Output of Distilled Water - ton per day
Heat Transfer Coefficient - B.Th.U. per hr. per sq. ft. per Deg. F. Nominal Temperature Difference
Operating Time - Days

Showing typical variation in heat transfer coefficient, output, and coil steam pressure, with operating time. Evaporator shell pressure, 0·5 lb per square inch gauge ; brine concentration factor, 2·5.

Fig. 1—Evaporator Performance Curves

how the rate of heat transfer falls rapidly due to the scale formation—the heat transfer coefficient falling from over 900 to less than 300 B.Th.U. per square foot per hour per degree Fahrenheit temperature difference, in the short time of twenty days. In this plant, it was possible to reduce the fall in output by allowing the steam pressure in the coils to rise as the scale increased ; but in many cases this is not possible, and the fall in output is more severe than is shown.

Composition of Sea Water

The solids in sea water are indicated by the typical example given in Table I‡ :

There are slight variations in the solid contents of sea water in different parts of the world, but it will be shown that they are not significant in the problem.

The Test Plant and Testing Considerations

It has usually been accepted that the weight of solids contained in sea water makes any form of water treatment to prevent scale formation too cumbersome and costly to be accepted. Scale formation and its removal have been regarded as unavoidable evils. It was considered however, that, if a detailed knowledge of its mechanism could be obtained, there might be a better prospect of attacking the problem of preventing the scale formation and that, in the long run, it would be necessary to carry out the investigation with a reasonably large-sized distilling plant.

The facilities available for testing were 20 miles from the sea and this necessitated the transport of large quantities of sea water. A large amount of experience was available in the use of synthetic sea water and it was known that such water gave appreciably different scale formation from that obtained with actual sea water. It was considered necessary, therefore, to use real sea water. All the sea water used was obtained at Troon, Firth of Clyde, and its composition compared closely with that given in British Standard 1170 : 1947. Typical analyses of the Troon water are given in Table II.

Table I—*Solids Contained in a Sample of Sea Water*

In ionic solution Dissolved solids	Lb per million lb of water
Calcium bicarbonate, $Ca(HCO_3)_2$	180
Calcium sulphate, $CaSO_4$	1,220
Magnesium sulphate, $MgSO_4$	1,960
Magnesium chloride, $MgCl_2$	3,300
Sodium chloride, NaCl...	25,620
	32,280

With the usual operating conditions for sea-water evaporating plants, scales are formed from : calcium carbonate, $CaCO_3$, known as calcite ; magnesium hydroxide, $Mg(OH)_2$, known as brucite, and calcium sulphate scales, $CaSO_4$, which may be anhydrite, hemi-hydrate or gypsum. The scale formed may be predominantly one or other of these scales or a mixture dependent upon the operating conditions ; but, owing to the number of factors involved and the variety of operating conditions, and also to the difficulty of obtaining reliable data under controlled conditions over a long period of time, the factors governing the deposition and incidence of these scales were not understood.

Table II—*Solids Contained in a Sample of Sea Water*

Sample taken from Troon, Firth of Clyde Dissolved solids	Lb per million lb of water Flood tide	Ebb tide
Calcium carbonate, $Ca(HCO_3)_2$ ...	186	183
Calcium sulphate, $CaSO_4$	1,210	1,170
Magnesium sulphate, $MgSO_4$	1,940	2,070
Magnesium chloride, $MgCl_2$	3,260	3,200
Sodium chloride, NaCl	25,700	25,650
	32,296	32,273
Specific gravity at 60 deg. Fah.	1·0256	1·0252
pH value	7·58	7·82

The main factors to be considered were the temperature and pressure at which evaporation takes place, the temperature difference across the heating surface, and the density of the brine in the evaporator. It was decided to use an evaporator provided with four coils with a separate steam supply to each coil, so that each coil could be operated with a different coil steam pressure, but a common shell pressure and brine density. Sea-water evaporators are most commonly operated somewhere in the range of 140 deg. to 220 deg. Fah., 2·88 lb to 17·2 lb per square inch absolute. For drinking purposes, it is considered desirable from the medical point of view that, to render any bacteria harmless, all the sea water used should be subjected to a temperature of 160 deg. Fah. or over.

With regard to brine density, it has been a common practice to use a blow-down equal to 50 per cent of the made water—that is, a brine concentration of 3. One school of thought considers that scale formation can be largely reduced by operating with a blow-down of 200 per cent of the made water—a brine concentration of 1·5. It was decided to run at evaporator vapour temperatures of between 140 deg. and 220 deg. Fah., with brine concentrations between 3 and 1·5, and with temperature differences between 20 deg. and 100 deg. Fah.

The steam supply to each coil was separately controlled and the condensate draining from each coil was measured separately. This quantity, and the temperature difference, were used to determine the rate of heat transfer obtained from each coil. The temperature differences were based on the saturation temperature corresponding to the steam pressure in each coil, recorded by the pressure gauge at the inlet to the coil, and the temperature of the vapour in the evaporator shell. These points should be borne in mind in assessing the possible accuracy of the data.

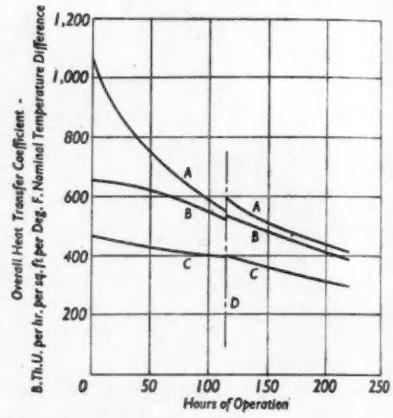
A running period of about 200 hours was found necessary, to obtain scale formations of reasonably measurable thickness and character ; to reduce the cost of the transport of the sea water, it was decided to use three coils only at various temperature differences. The fourth coil was left as an idle coil. For convenience in control, the coil steam pressures were set and the temperature differences that resulted were accepted. The plant was operated continuously for five days a week with a shut-down on Saturdays and Sundays.

It was known that the calcium-sulphate scales could be avoided by operating with a sufficiently low brine density ; so, to reduce the variables to be considered, most of the testing was carried out with a blow-down of about 100 per cent of the made water—giving a brine concentration of 2.

Testing Procedures and Some of the Test Results

The plant was run at each set of conditions for about 200 hours or more and the results were logged every four hours. The sea water and the evaporator brine were analysed at frequent intervals. At the end of a run, samples of the scales formed on the coils, the evaporator shell, and a deflector plate in the evaporator were analysed. After each run, the coils and evaporator shell were cleaned mechanically and with a solution of hydrochloric acid.

In the early tests, the scale samples were taken at intervals along the length of each coil ; but the samples were found to be very similar and the sampling was limited to two places on each coil.


Overall Heat Transfer Coefficient - B.Th.U. per hr. per sq. ft. per Deg. F. Nominal Temperature Difference
Hours of Operation
A
B
C
D

No treatment. Evaporator vapour temperature, 160 deg. Fah.; shell pressure, 4·74 lb per square inch abs.; brine concentration factor, 2: duration of test, 220 hours.
A Coil No. 1 ; 95·8 deg. Fah. nominal temperature difference.
B Coil No. 2 ; 59·5 deg. Fah. nominal temperature difference.
C Coil No. 3 ; 32 deg. Fah. nominal temperature difference.
D Week-end halt.

Fig. 2—Variation of Heat Transfer Coefficient with Operating Time

Fig. 2, plotted from a test with an evaporation temperature of 160 deg. Fah., shows how the heat transfer coefficients fall as scale accumulates. The week-end halt caused a slight discontinuity, but did not affect the general trends significantly.

The data show that, starting from the low temperature, the scale formed is predominantly $CaCO_3$, which, as the evaporation temperature passes 170 deg. Fah., is replaced by a $Mg(OH)_2$ scale. Fig. 3 shows the incidence of the $CaCO_3$ and $Mg(OH)_2$ scales, with evaporation temperature and nominal temperature differences of 22 deg. and 80 deg. Fah. The curves show the amounts of $CaCO_3$ and $Mg(OH)_2$ as a percentage of the total scale present.

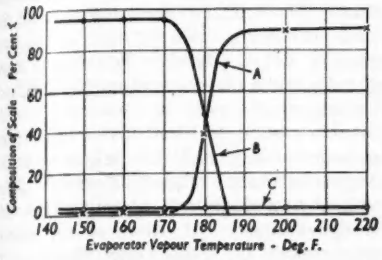
Sea-Water Solubilities

The soluble impurities found in sea water are mostly carried away from the land by water flowing to the sea. The bulk of such soluble solids is sodium chloride, which is extremely soluble. It is probable that the amount of sodium chloride in the sea has been slowly increasing over the ages. Sodium chloride need

* Institution of Mechanical Engineers, January 30th. Extracts.
† Engineering and Technical Director, G. and J. Weir, Ltd., Glasgow.
‡ From British Standard 1170 : 1947 (British Standards Institution).

not be considered in the scale problem because its precipitation point is not normally reached in sea-water distilling plants.

Analyses of river waters show that the proportions of carbonates and sulphates to chlorides in such waters are much greater than in sea water. The amounts of carbonates and sulphates in sea water are probably controlled largely by the biochemical processes of the organic life in the sea. It would appear, however, that, so far as bicarbonates and carbonates are concerned, the controlling factor is the equilibrium between the gases of the atmosphere and the gas content of the sea water, the surface sea water being in



Nominal temperature difference, about 22 deg. Fah.; brine concentration factor, about 2.
A Magnesium hydroxide, $Mg(OH)_2$. *B* Calcium carbonate, $CaCO_3$. *C* Calcium sulphate, $CaSO_4$.

Fig. 3—Main Constituents of Scale on Evaporator Coils at Different Evaporator Vapour Temperatures

solution equilibrium with the gaseous carbon dioxide (CO_2) content of the air, with an average partial CO_2 gas pressure of 0·0003 atmosphere.

Within the sea water, there is an equilibrium between the dissolved CO_2 gas present and the combined carbonic acid, H_2CO_3. It has been calculated that, of the total carbonates in solution in the sea, about 96 per cent are in the form of bicarbonates, $(HCO_3)^-$, and about 4 per cent are in the form of carbonates, CO_3^{--}.

Any change that tends to increase the concentration of the carbonate ions results in the precipitation of calcium carbonate.

Reactions in the Evaporator

The calcium bicarbonate and calcium carbonate present in sea water are almost completely ionised ; thus :

$$Ca(HCO_3)_2 \rightleftharpoons Ca^{++}+2HCO_3^-$$

$$CaCO_3 \rightleftharpoons Ca^{++}+CO_3^{--}$$

As the sea water is heated and evaporated, the partial CO_2 gas pressure within the water is reduced, resulting in the bicarbonate ions breaking up into carbonate ions, water and gaseous carbon dioxide—the carbon dioxide gas leaving the water with the water vapour of evaporation, thus :

$$2HCO_3^- \longrightarrow CO_3^{--}+H_2O+\overline{CO_2}$$

The conditions within an evaporator are in a state of dynamic equilibrium. A continuous supply of sea water is being fed into the evaporator, where it mixes with a concentrated brine that is being heated and evaporated. At the same time, there is a continuous outflow of concentrated brine from the evaporator.

The concentration of the solids in the brine in the evaporator is determined by the relations between the rate at which sea water is fed into the evaporator, the rate at which brine is withdrawn from the evaporator, and the rate at which solids are deposited as scale or sludge on the surfaces in the evaporator.

Heating and evaporation result in an increase in the concentration of the carbonate ions in a brine that is saturated with carbonate ions relative to calcium ions, with the result that some of the carbonate ions combine with calcium ions, and $CaCO_3$ is precipitated as follows :—

$$Ca^{++}+CO_3^{--} \rightleftharpoons \underline{CaCO_3}$$

This is the first action which takes place, and $\underline{CaCO_3}$ can be held in suspension in the brine, and on the evaporator surfaces as scale, in equilibrium with its ions as follows :—

$$\underline{CaCO_3} \rightleftharpoons Ca^{++}+CO_3^{--}$$

This is the condition that prevails at evaporation temperatures of 140 deg., 150 deg. and 160 deg. Fah. Small inclusions of other compounds in the scale are probably the result of fortuitous trapping in the scale.

While a $CaCO_3$ scale is being experienced with evaporation temperatures of 140 deg. to, say, 180 deg. Fah., another increasing reaction is taking place with increasing temperature, resulting ultimately in a $Mg(OH)_2$ scale. As the evaporation temperature is increased, some of the carbonate ions, CO_3^{--}, break down ; then, in conjunction with water, they give off carbon dioxide as a gas and give rise to the formation of hydroxyl ions. These combine with magnesium ions to form $Mg(OH)_2$ as a precipitate ; thus :

$$CO_3^{--}+H_2O \longrightarrow \overline{CO_2}+2OH^-$$
$$Mg^{++}+2OH^- \longrightarrow \underline{Mg(OH)_2}$$

In all the tests carried out, the pH of the concentrated brine falls generally within the range of 8–9. The hydroxyl ions in solution, for pH values of 8 and 9, are respectively 0·017 lb and 0·17 lb per million pounds of water. These are insignificant amounts ; practically all the hydroxyl ions formed by the break-up of carbonate ions combine with magnesium ions to form $Mg(OH)_2$, in suspension in the brine or precipitated as a scale. From the practical point of view of this problem, $Mg(OH)_2$ can be regarded as insoluble.

In the tests, the $Mg(OH)_2$ formed increased with temperature and remained in suspension in the brine up to an evaporation temperature of about 180 deg. Fah. At about this temperature and above, $Mg(OH)_2$ was precipitated as a scale on the evaporator surfaces, and, as $Mg(OH)_2$ appeared in the scale, the proportion of $CaCO_3$ in the scale fell until it disappeared altogether at the higher temperatures.

It will be seen that the bicarbonate ions in the sea water may provide one of two alternative forms of scale, the alternative results of the break-up of the bicarbonate ions being as follows :—

(1) $$2HCO_3^- \longrightarrow CO_3^{--}+H_2O+\overline{CO_2}$$
$$Ca^{++}+CO_3^{--} \rightleftharpoons \underline{CaCO_3}$$

giving calcium carbonate as a scale or precipitate in suspension.

(2) $$2HCO_3^- \longrightarrow CO_3^{--}+H_2O+\overline{CO_2}$$
$$CO_3^{--}+H_2O \longrightarrow 2OH^-+\overline{CO_2}$$
$$Mg^{++}+2OH^- \longrightarrow \underline{Mg(OH)_2}$$

giving magnesium hydroxide as a scale or precipitate in suspension.

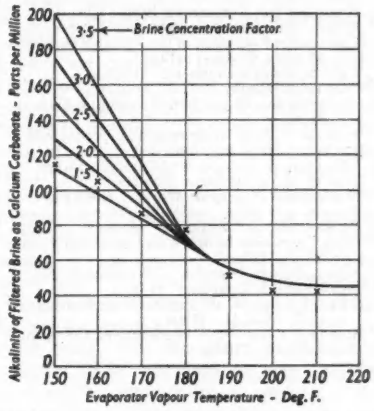
In both cases, carbon dioxide is released as a gas.

The bicarbonate ion is, therefore, responsible for both the $CaCO_3$ and the $Mg(OH)_2$ scales. The incidence of the composition of the scales is dependent upon temperature, while the amount of scale at a given temperature increases with the amount of sea water supplied to the evaporator. Scale from sea water evaporators in service operation sometimes shows a composition of appreciable amounts of $CaCO_3$, $Mg(OH)_2$ and $CaSO_4$; this has hitherto rather confused the problem.

Following the tests reported herein, scales from large sea-water evaporators have been carefully examined and the scale structure from some plants was found to be stratified, starting with a $CaCO_3$ scale adjacent to the surface and followed by a $Mg(OH)_2$ layer and an outer layer of $CaSO_4$. As the formation of scale accumulates the local temperature conditions are changed by the resistance to heat flow set up by the scale, the resulting conditions successively giving rise to the different scales.

The test data showed that only a part of the total amount of bicarbonate and carbonate ions fed into the evaporator go to scale formation. Some of the bicarbonate and carbonate ions, some of the $CaCO_3$, and some of the $Mg(OH)_2$, leave with the blow-down. A portion of some of the bicarbonate and carbonate ions leaves as carbon dioxide gas. The balance remains in the scale. This balance is the amount of bicarbonates and carbonates that has to be dealt with, as a minimum, if scale formation is to be prevented ; and it appeared to be reasonably small. The amount of $CaCO_3$ and/or $Mg(OH)_2$ in solution or suspension in the brine, and discharged with the brine, was now appreciated to be of importance ; it was unfortunate that this had not been appreciated earlier in the investigation, as the opportunity of obtaining considerable data on this aspect was thus missed.

The data obtained at 170 deg. Fah., brine concentration 2, were examined to ascertain the state and proportion of the scale-forming solids in the scale formed in the evaporator and in the blow-down. The calcium in the scale formed in the evaporator was estimated at about 9 lb, out of a total weight of feed water of 76·3 tons fed



Various evaporation temperatures and brine concentrations.
× Experimental values from tests of six hours at brine concentration 2.

Fig. 4—Alkalinity of Filtered Brine

into the evaporator during the run. The difference between the calcium fed into the evaporator and the calcium discharged with the blow-down was 9·4 lb. The difference in magnesium was estimated from the scale analyses to be 0·15 lb.

Summarised :—

Total Ca^{++} in the scale=0·123 lb per ton of sea water ;

Total Mg^{++} in the scale=0·002 lb per ton of sea water.

Of an alkalinity of 115 lb per million pounds of water (p.p.m.) (expressed as $CaCO_3$) in the sea water ;

41 p.p.m., or 36 per cent, was removed as scale, or as $CaCO_3$ in suspension ;

43 p.p.m., or 37 per cent, was removed in solution ;

31 p.p.m., or 27 per cent, was decomposed, resulting in CO_2 as a gas and $Mg(OH)_2$ as scale or in suspension.

At this point it was decided to obtain data on the amount of the alkalinity carried in solution in the brine. Tests were run at a given evaporation temperature, feeding with sea water and boiling the brine at a constant level, so that the concentration slowly increased to 3·5. No blow-down was used, and each test occupied between five and eight hours. The brine was sampled as the concentration increased.

The alkalinity was generally as shown in Fig. 4, but it should be emphasised that the curves given indicate trends only, because the actual results had a wide scatter. The tests indicated that, up to a temperature of about 170 deg. Fah. the alkalinity varied with concentration ; but at higher temperatures the alkalinity appeared to be independent of the concentration and fell slightly with increasing temperature. The tests were not truly representative of evaporator operating conditions, because there was no blow-down, and it is possible that the length of time to obtain completion of reactions may be a significant factor. Nevertheless, the curves are of interest in showing the general trend and giving a rough indication of numerical significance.

(To be continued)

Factory Equipment Exhibition.—The first National Factory Equipment Exhibition is to be opened at the Royal Horticultural Hall, London, on March 23, 1953. The exhibits will include mechanical handling equipment, costing and accounting systems, safety equipment, protective clothing, automatic tools, dust removal systems and workers' welfare equipment.

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POWER FROM NUCLEAR ENERGY

In a statement to the House of Commons last week, Mr. Sandys, as Minister of Supply, reviewed the present position of work on the production of electric power from nuclear energy. His statement was welcomed by the House, but it appeared from its reception that its complexity was presenting certain difficulties. The fissile fuel used for the generation of nuclear power gives rise to streams of fast-moving electrically charged particles, and what would seem simpler than the employment of some ingenious means which would bind them together to form just the kind of current that is desired for electric supply purposes? But the position reached at the moment is far less simple. Instead, the initial electric forces are used to produce kinetic energy in the fissured nuclei which, on being converted into the form of heat, is used to raise the temperature of a suitable circulating fluid, whether gas or liquid, to as high a temperature as the materials so used will conveniently stand; it is next passed to a form of boiler which will produce the steam required to drive a normal electric generator, and so at long last produce the desired electric current. This is very far from the direct and simple conversion one may picture as the ideal, and even if it is not so many years, perhaps, from achievement, it seems a long way from our grasp at the moment—so far, in fact, that the Minister's statement did not even mention it as a possibility. Maybe he did not care to go beyond the information his advisers had given to him, and therein was wise. But he did say that the most certain method of power generation was to build an improved uranium reactor to be enclosed for safety's sake, with its circulating fluid in a pressure vessel and that a useful by-product of the plant would be a supply of plutonium as supplementary fuel. He added that the design of such a reactor was in hand and a suitable site was being selected for its erection.

One of the surprises of the statement was that of hearing that it was proposed to delay the application of nuclear energy to the propulsion of mobile vessels until more is known of the performance of stationary plants. This is an attitude very different from that taken by the former President of the U.S., who stated only a few months ago that the first American nuclear plant for submarine use was already nearing completion, and we have seen nothing since stated to the contrary. In fact, the last report of the U.S. Atomic Energy Commission, reviewed in our issue of October 17th last, stated that the keel plate for the first nuclear powered submarine, U.S.S. "Nautilus," was laid on June 14th, and gave the detail that one of the experimental reactors would make use of a liquid metal coolant and be housed in a steel sphere some 225ft in diameter.

In the United States much more use is made of private firms for work of this character than is customary in this country, and it is impossible not to feel some sympathy for the suggestion made to the Minister by a Labour Member, Mr. Bellenger, that we might be well advised to follow more closely the American practice in such matters. In a recent interview which Dr. Gordon Dean, Chairman of the U.S. Atomic Energy Commission, gave to the Editor of the *Chicago A.E. Bulletin*, he remarked: "As to the motives of our contractors, I believe they vary from company to company—the desire to keep abreast of new developments in a new field that holds tremendous promise for the future—the prestige that stems from being connected with a vital enterprise—and from being a pioneer in a promising new industry." We do not doubt that these same motives would operate just as strongly in this country.

DEVELOPMENT IN STEAM LOCOMOTIVE DESIGN

At this time, when steam locomotive performance in Great Britain is being subjected to such intensely critical analysis on the stationary testing plants at Swindon and Rugby, and the capacity of certain classes has been increased to a remarkable extent by relatively small dimensional changes at the front end, it is naturally interesting to look back over the last fifty-odd years and single out the highlights in a chain of fairly continuous development. It is perhaps an even more absorbing study to compare the test results obtained in earlier trials with those recently published by the Railway Executive in successive *Bulletins* of the Locomotive Testing Committee. Such study will be easier in future, for in the fine book, noted on the opposite page, our well-known contributor, Mr. E. C. Poultney, has collated the details of many notable test runs of the past within a single volume. While one must naturally make the reservation that methods of measurement in those earlier trials were probably a good deal less precise than those demanded to-day, and that data concerning one particular class of locomotive were often confined to a single run, or round trip with the dynamometer car, some of the earlier performances do cause one furiously to think, when the weight and nominal tractive power of the locomotives concerned are taken into account. It is the Bowen-Cooke express locomotives of the former London and North-Western Railway that attract most of the limelight in this respect, though in fairness to the Great Western it is true to say that up to 1914 no Churchward engine had been subjected to a dynamometer car trial of the "all-out" character run with the "George the Fifth," from Euston to Crewe in 1910, or with the "Ralph Brocklebank," between Euston and Carlisle in 1913. These earlier trials can be regarded as in some way anticipating the "all-out" trials of one of Sir William Stanier's "Pacifics," the "Duchess of Abercorn," between Crewe and Glasgow in 1939.

On an outstanding run with the "George the Fifth" a train of 360 tons was taken over the 158 miles from Euston to Crewe at an average speed of 60 m.p.h. start to stop. This involved a coal consumption of 45 lb per train-mile, which on the general standards of performance prevailing in 1910 would be considered very good; but a considerable measure of improvement can be noted since that time, and on the basis of test results obtained at Swindon, one of the new British standard class "4" 4-6-0s could do the same job on a consumption of 30 lb to 35 lb per mile. It is more particularly the boiler performance of the "George the Fifth" that commands attention. The average indicated horsepower throughout the run was more than 1000, sustained by a 4-4-0 locomotive weighing, without its tender, just under 60 tons; the boiler was provided with a deep narrow firebox, with a grate area of 22·4 square feet, and on that grate coal was burned at an average rate of 123 lb per square foot of grate area per hour. This, moreover, was no isolated case. Analysis of many carefully compiled records of forty years ago shows that the same standard of running prevailed on journey after journey with the crack trains into and out of Euston, and in some instances the "George the Fifth" test standards were definitely surpassed. The locomotives were relatively easy to fire, and they could burn, effectively, a large volume of coal on a thick bed of fire. The four-cylinder 4-6-0s of the "Claughton" class in the 1913 trials achieved an even greater cylinder horsepower in relation to their

nominal tractive effort—an average of 1370 i.h.p., with 23,700 lb tractive effort, against 1080 i.h.p. and 20,000 lb with the "George the Fifth." The coal consumption was not quoted, but with a much larger grate of 30·5 square feet the fire would be thinner. The "Claughtons" needed considerably more skill in firing, and although the maximum efforts were extremely good for the period the reputation of the class as a whole suffered from the occasions when inexperienced firing led to poor steaming. On the other hand, a locomotive engineer brought up on the Midland Railway once remarked rather enviously of the "George the Fifths" that they would steam under the efforts of a navvy. They were more generally reliable in consequence.

Another remarkably interesting passage in Mr. Poultney's book concerns the trials of two North Eastern "Atlantic" engines between Newcastle and Edinburgh shortly after the grouping of the railways. The trials were arranged as a comparison between two-cylinder and three-cylinder propulsion. On the face of it this comparison could be made on very reasonable terms, since the former North Eastern Railway used the same boiler on both types of locomotive. The boiler performance was, indeed, very good, the evaporation averaging as much as 19,000 lb per hour on one journey, when the steam temperature was 600 deg. Fah.; but both engines showed up as being heavy on coal. The three-cylinder machine was the better of the two, with an overall figure of 4·6 lb of coal per drawbar horsepower hour, against a corresponding figure of 6 lb for the two-cylinder machine. This result was attributed at the time to the superiority of three-cylinder propulsion; but subsequent experience has shown that relatively small changes to the valve gear can bring about an almost sensational reduction in coal consumption, as Sir Nigel Gresley demonstrated later on his "Pacific" engines, following the experience of the 1925 interchange trials with the Great Western "Castle" class. The North Eastern "Atlantic," and particularly the two-cylinder variety, seem, from these results, to have suffered from poor cylinder design; but in those pregrouping days many of the old railway companies were very self-contained in their technical policy. Exchange of views was the exception rather than the rule, and so one had a group of north-country express locomotives using 4½ lb to 6 lb of coal per drawbar horsepower hour, while the Churchward 4-6-0s of the Great Western were using no more than 3 lb. To-day, the long experience of Swindon in the testing of locomotives is being made available to all regions of British Railways. We have already referred to the remarkable results obtained from engines of L.M.S. origin, and in recent months one of the late Sir Nigel Gresley's large 2-6-2 mixed traffic engines of the "V2" class has been undergoing full-dress trials on the Swindon stationary plant. We look forward to the publication of many more test *Bulletins*. Meanwhile the older ones amongst us, turning over the pages of Mr. Poultney's book, may reflect nostalgically upon how much better many famous locomotives of the past might have been if present-day testing methods had been generally available thirty to forty years ago.

Literature

British Express Locomotive Development, 1896–1948. By E. C. POULTNEY, London: George Allen and Unwin, Ltd., Ruskin House, 40, Museum Street, W.C.1. Price 21s.

THIS book, which consists in the main of a reprint of a series of articles published in our contemporary, *Modern Transport*, is the outcome of the author's desire to have a book of his own making, to quote his own Preface, "on some phase or another of locomotive development to remain as a memento of a life freely given to the steam locomotive, regarded with a deep and abiding affection." As an old Furness Railway man, and one with a specialist's knowledge of modern valve gears, Mr. Poultney has been able to bring the critical outlook of a practical locomotive engineer to what has obviously been a labour of love. His story begins with the Railway Races of 1895, passes by way of the first "Atlantics" and 4–6–0s to a chapter on Churchward's great work at Swindon, which chapter Mr. Poultney aptly titles "The Keystone of the Arch." From this he proceeds, stage by stage, to "Modern High-Powered Locomotives." If much of the story is well known it is good to have it in one compact volume. The illustrations are numerous; but they are, almost without exception, reproductions of official views, and are useful rather from their documentary value than from any pictorial or artistic quality.

Jane's Fighting Ships, 1952–53. Edited by R. V. B. BLACKMAN, London; Sampson Low, Marston and Co., Ltd., 25 Gilbert Street, Oxford Street, W.1. Price £4 4s.

THE cost of printing and producing books is still rising, but this year the publishers of *Jane's Fighting Ships* have taken the courageous step of reducing the number of pages rather than again increasing the price. None of the essential features of this excellent work of reference, however, has been sacrificed and the improved layout adopted two years ago of arranging names, data drawings and photographs, &c., in an ordered pattern has been retained. But out-of-date photographs have been removed and this has made it possible to add some 450 up-to-date illustrations. A noticeable improvement in this volume is the absence of speculative and unreliable matter of previous years. Indeed, the Foreword, summarising the principal points of interest in the world's navies, might well have been announced by the First Lord during a debate on the Navy Estimates. Similarly, the Russian section, which in every edition since the war the reader has been warned to treat with reserve, now omits an artist's impression and fairly precise details of the armament and machinery of Soviet super-battleships reported to be under construction. There never has been any reliable evidence of the existence of these ships and the brief sentence in the current volume referring merely to persistent reports of their construction reads much more like the authentic information we expect to find in *Jane's*. Gone, also, is any reference to the 1000 submarines of the new Soviet building programme; the number under construction is reported to be 120, which seems well within the capacity of Russian dockyards. Nor is there any reason to doubt the definite figure of 370 submarines of all types in commission or reserve, as this number is little higher than the authoritative estimates announced both in this country and the United States. But the underwater speed of 18 knots given for the improved "K" class now under construction is more open to question. *Jane's* states that these vessels are to be fitted with a snort which indicates they will be electrically driven, and no battery—unless other essential equipment is to be sacrificed—is large enough to give a full speed output lasting longer than an hour.

Next to the Russian section, the reader will find most interest in the British and United States navies, which, *Jane's* emphasises, have had second thoughts about scrapping ships, not only in the normal process of wastage and replacement, but vessels which had, in fact, been earmarked for disposal—as, for example, H.M.S. "Pioneer," an aircraft maintenance carrier. It is to be regretted that the publishers persist in placing carriers—not to mention carrier maintenance vessels—before battleships in the order of categories. None of the reasons for this innovation given in the 1950–51 volume has much real force behind it. It is not numbers in commission, size, machinery power or complication of construction which count. The only true criterion is fighting power and the sole reason why the majority of British and United States battleships are in reserve is that our potential enemy possesses no ships of this kind. On the other hand, carriers are likely to be required in large numbers for offensive operations in enemy waters and for anti-submarine operations.

The United States Navy has over 100 of these vessels, besides 15 battleships, 75 cruisers, 350 destroyers, 270 frigates and other escorting vessels, 220 minelayers and over 3500 auxiliary ships and amphibious vessels. The Foreword also draws attention to an entirely new category of warships which are now being constructed, or converted, for the United States Navy—vessels fitted out primarily for purposes of tactical command and administration. These functions have until now been carried out by the flagship, which has to take her full share of the fighting. Other pages of special interest are those dealing with the Dominion navies which are expanding rapidly and will soon provide a substantial addition to British seapower. Australia has already purchased two light fleet carriers from Britain and is building four "Daring" class destroyers, while Canada has recently purchased the "Powerful"—a carrier whose construction has been suspended since the war—to replace the "Magnificent," and is constructing fourteen anti-submarine escorts and fourteen coastal minesweepers of a new type. In this connection the publishers might note for the next edition, now in course of preparation, that it is confusing to read on one page that the construction of the "Powerful" is suspended and on the next that she is to be completed for the Canadian Navy.

BOOKS RECEIVED

The Economic Aspects of Nationalisation in Great Britain. By A. M. De Neuman. Cambridge: Students' Bookshops, Ltd., 4, Trumpington Street, Cambridge. Price 8s. 6d.

Workshop Calculations, Tables and Formulae. Tenth Edition. By F. J. Camm. London: George Newnes, Ltd., Tower House, Southampton Street, Strand, W.C.2. Price 7s. 6d.

Hydraulics and The Mechanics of Fluids. Ninth Edition. By E. H. Lewitt. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 25s.

Harwell, The British Atomic Energy Research Establishment. London: Director of Publications (PI), Her Majesty's Stationery Office, Atlantic House, Holborn Viaduct, E.C.1. Price 6s.

Selected Government Research Reports: Volume I, Plastics. Edited by Professor E. K. Rideal. London: Her Majesty's Stationery Office, York House, Kingsway, W.C.2. Price £1 15s.

The Development of Engineering Metrology. By F. H. Rolt. London: Technical and Publications Department, The Institution of Production Engineers, 36, Portman Square, W.1. Price 5s.

Obituary

SIR LEOPOLD H. SAVILE, K.C.B.

It is with great regret that we record the death, on January 28th, at 23, Pelham Crescent, London, S.W.7, of Sir Leopold Halliday Savile, K.C.B. His long and distinguished career as a civil engineer was concerned primarily with dock and harbour engineering, and he made a noteworthy contribution in this sphere. Sir Leopold was born on August 31, 1870, at Ballendrick, Scotland, and he was educated at Marlborough and King's College, London. He served as a pupil under the distinguished engineers, Sir John Wolfe Barry and H. M. Brunel, and whilst with these engineers he was engaged on the new entrance works at the Tyne docks and at the new docks at Barry. This was his first introduction to dock and harbour engineering, to which he devoted practically the whole of his engineering career.

In 1896 Sir Leopold went to India, where he assisted in the construction of the Southern Punjab Railway and the Bengal North-Western Railway. On his return to this country in 1898 he gained some further experience of dock work, acting as resident engineer at the Ramsden Dock, Barrow-in-Furness. In 1902 he made his first visit to Australia, reporting on a proposed new harbour at New South Wales; in the following year he prepared a scheme in connection with new harbour works at Singapore.

Sir Leopold's varied career took him again to India during 1904, as deputy chief engineer to the Bombay Port Trust, in charge of the construction of the Alexandra Dock. This major project consisted of a wet dock, 50 acres in extent, with berths for seventeen ships, and also included an entrance lock and a dry dock, each 1000ft in length. He remained in Bombay until 1919, when he was appointed Civil Engineer-in-Chief to the Admiralty in succession to Sir Alexander Gibb. With this new appointment Sir Leopold took charge of all Admiralty dockyards at home and abroad. He was concerned with the maintenance and construction of new Admiralty works which, during the thirteen years he was at the Admiralty, included several outstanding schemes, of which the Singapore Naval Base was probably the most important. One of these schemes, which is of rather particular interest, as it falls outside the normal scope of the dock and harbour engineer's work, concerned the demolition of the German defence works and harbour on the island of Heligoland, which was undertaken after the 1914–18 war. Sir Leopold presented a paper on this subject to the Institution of Civil Engineers (*Minutes of Proceedings*, Vol. 220, page 55, 1924–25, Part 2), in which he pointed out that the work was believed to be by far the largest one of deliberate demolition ever undertaken, involving harbour works and fortifications which had taken upwards of twenty-five years to construct at a cost of about £35,000,000. A description of the various works on the island, and of the methods of demolition which were employed, was included in the paper.

On his retirement from the Admiralty in 1932 Sir Leopold became a partner in the well-known firm of consulting engineers, Sir Alexander Gibb and Partners. During the course of his work with that firm he was concerned with a large number of engineering works, including the Kincardine bridge, Vizagapatan harbour, and extension works at the ports of Rangoon, La Guaira, Venezuela, and Burnie, Tasmania. He also dealt with the civil engineering work for several large thermal power stations, including Ipswich, Littlebrook, Earley, Meaford, and Bromborough.

In 1939 the Commonwealth Government of Australia decided to construct a modern dry dock, capable of accommodating the largest capital vessels as well as commercial vessels of the "Queen Mary" class. Sir Leopold Savile visited Australia and investigated sixteen possible sites, with a view to selecting the most suitable for this major work. The site which he recommended and which was eventually adopted was in Sydney harbour, downstream of the harbour bridge and situated between the mainland and Garden Island. His firm was instructed to design the dock and superintend its construction, and later, it was officially opened by the Duke and Duchess of Gloucester in March, 1945, and named the Captain Cook graving dock. This dock, 1133ft long and 148ft wide, is the largest dry dock in the Southern Hemisphere and entailed the reclamation of over 35 acres between the mainland and Garden Island. Constructional work was commenced in 1940 and completed in 1945, the dock being available for the service of the British Pacific Fleet in the final offensive against Japan.

Sir Leopold H. Savile

Sir Leopold Savile retired from his partnership in Sir Alexander Gibb and Partners in 1947 and from that date until his death acted as a consultant to the firm, to which his advice on major engineering problems, and especially those concerned with dock and harbour engineering, was of great value.

Sir Leopold Savile became an associate member of the Institution of Civil Engineers in 1895, a full member in 1914 and president during the 1940–41 session. He wrote several papers for the Institution and was awarded the Crampton Prize in 1904 and the George Stephenson Gold Medal in 1925 for his paper entitled "Demolition of the Harbour and Defence Works of Heligoland," which is mentioned above. The importance of historical study in engineering is a subject not without topical interest, a study of the history of the development of a particular branch of engineering being indispensable, in some opinions, to a full understanding of the significance of present-day practice. In this respect Sir Leopold Savile's presidential address, delivered on November 6, 1940, is noteworthy. His subject was the ancient harbours of the early Mediterranean civilisations up to the time of the Romans. He described harbours such as those at Tyre and Alexandria, and gave examples of early Grecian and Roman harbours. The address was abstracted in our issue of November 8 and 15, 1940, and contained an authoritative account of some of these old works. Sir Leopold noted that "the similarity of the ancients' treatment of problems to the methods of the modern engineer is in many cases remarkable." "The Egyptians," he noted, "used the cyclopic dry-stone structure; the Greeks used large ashlar masonry held together by iron dowels and lead; the Romans used their famous, almost everlasting, concrete made of pozzuolana, lime and stone. . . . The Romans were essentially a practical people and they introduced many new methods, among which the most outstanding were the use of the arch, the cofferdam, hydraulic cement (pozzuolana), and the driving of piles in deep water."

Sir Leopold was made a C.B. in 1925 and K.C.B. in 1929. Apart from his presidency of the Institution of Civil Engineers, he was an associate of the Institution of Naval Architects and a member of the Institution of Engineers of Australia.

PROFESSOR C. J. HAWKES, O.B.E.

It is with regret that we record the death of Professor C. J. Hawkes, which occurred at his home at Eastbourne on Friday, January 30th. Professor Hawkes, who was in his seventy-third year, retired from the Royal Navy with the rank of Engineer Commander and at the time of his death was Emeritus Professor of Engineering at King's College, Newcastle upon Tyne.

Charles John Hawkes was born on April 22, 1880, at New Brompton, Kent, and upon completing his education at Sir J. Williamson's school at Rochester in 1895, he served

an apprenticeship in H.M. Dockyard at Chatham, and received marine engineering training in the dockyard school. Five years later he was appointed Engineer Sub-Lieut., and received further instruction over the next three years at the Royal Naval College at Greenwich. Then followed an appointment to H.M.S. "Montagu," after which he carried out the duties of assistant to the chief engineer of H.M. Dockyard, Sheerness, until 1907. For a year Professor Hawkes served on the staff of the director of Admiralty Dockyards, and was subsequently appointed to H.M.S. "Black Prince" for service afloat, and on coming ashore he joined the staff of the Engineer-in-Chief with the rank of Engineer-Lieut. This appointment lasted for two years and then from 1912 to 1914 he acted as joint secretary to the Royal Commission on Fuel and Engines, followed by a further year on the staff of the Engineer-in-Chief. Professor Hawkes' next appointment was assistant secretary to the Board of Inventions and Research, where he dealt with inventions relating warship construction, propelling machinery, to torpedoes and aircraft engines. In 1917 he became the first superintendent of the Admiralty Engineering Laboratory in South Kensington and was engaged mainly upon design and experimental work concerned with oil engines. He spent three years in this post and then, in 1920, he was appointed Professor of Engineering at King's College, Newcastle upon Tyne, and continued to occupy the Chair until his retirement in 1946. Professor Hawkes, who was made O.B.E. in 1939, read a number of papers before the technical societies and was a member of the Institution of Mechanical Engineers, and also an Honorary Fellow of the North-East Coast Institution of Engineers and Shipbuilders, of which Institution he was president from 1936 to 1938. He was elected a vice-president of the Institution of Naval Architects in 1940 and was also an Honorary Member of the Society of Naval Architects and Marine Engineers (U.S.A.).

RHYS JENKINS

IN our last issue, we made a brief announcement of the death of Mr. Rhys Jenkins, M.I.Mech.E., which occurred on January 27th, at his home at 45, St. Helen's Park Road, Hastings. Mr. Jenkins, who was in his ninety-fourth year, was an acknowledged authority on industrial history, and in particular on the history of engineering. A great deal of his professional career was spent in H.M. Patent Office, where he was a senior examiner until his retirement in 1920.

Rhys Jenkins was born on September 29, 1859. He served an apprenticeship in the engine works of Nevill Brothers at Llanelly, and then spent a few years in the drawing office of John Fowler and Co., Ltd., Leeds. Subsequently, he worked for a time with Greenwood and Batley, Ltd., Leeds, with Hornsby and Sons, of Grantham, and with Marshall Sons and Co., Ltd., Gainsborough. In 1884, Mr. Jenkins secured an appointment on the examining staff of the Patent Office, later becoming a senior examiner. About the time of his appointment to the Patent Office, Mr. Jenkins began the systematic collection of notes, transcripts and extracts from printed and manuscript sources relating to numerous aspects of industrial history. The classification and arrangement of the wealth of material that he gathered occupied his leisure hours for over fifty years. Moreover, a great deal of that material has been made available in the form of papers, lectures and books, of which Mr. Jenkins was the author. Many of his writings were published in THE ENGINEER, under the title of "Links in the History of Engineering." The first of his articles under that title appeared on December 7, 1917, and dealt with the beginnings of iron founding in England. That series by Mr. Jenkins continued until 1920, his final article dealing with John Farey's book (1827) entitled *A Treatise on the Steam Engine, Historical, Practical and Descriptive.*

Mr. Jenkins' retirement from the Patent Office in 1920 occurred when proposals for the formation of the Newcomen Society for the Study of the History of Engineering and Technology were taking shape. He was an enthusiastic member of the Society from its very beginning and maintained an active interest in its affairs to the end of his days. As soon as the Society was founded, Mr. Jenkins began the long list of valuable contributions which are to be found in its *Transactions* under his name. They all reveal the thoroughness of his researches and the breadth of his knowledge. He was elected president of the Newcomen Society in 1926, and entitled his presidential address "Observations on the Rise and Progress of Manufacturing Industry in England." It dealt with a variety of industries—the manufacture of salt, tin smelting, lead smelting, wool, brewing, mining, glass and paper-making—and also with the introduction and development of mechanical power in industry. In 1936, the Newcomen Society published a collection of Mr. Jenkins' earlier papers as a token of the esteem in which he was held, and with the laudable object of making them available to a larger number of people. The collection includes some of the papers which have appeared in our pages. Another work which revealed Mr. Jenkins' painstaking research was the memorial volume, published in 1927, on *James Watt and the Steam Engine*, in the preparation of which he collaborated with his friend, the late H. W. Dickinson.

In recent years, perhaps, Rhys Jenkins had devoted more attention to the history of iron than to other subjects, but there was literally no technical matter about which he could not supply information from his notes or his memory. That information he was always ready to impart to serious workers. He was, by nature, very quiet and unassuming, but was always listened to with the closest attention and respect when he gave advice at the council table or spoke at meetings. The world has lost in him an antiquarian of the first rank.

PROFESSOR N. A. V. PIERCY

WE record, with deep regret, the death of Professor Norman Augustus Victor Piercy, which occurred on Sunday, February 1st, at 3, King's Bench Walk, London, E.C.4. Professor Piercy, who was sixty-one, had been concerned with many aspects of mathematical and experimental research in aerodynamics and was regarded as one of the pioneers in aeronautical education.

Professor Piercy was born at St. John's Wood, London, on August 10, 1891. He was educated at Hampton Grammar School, and in 1908 was apprenticed to Yarrow and Co., Ltd., Scotstoun, where he stayed until 1913. By that time he had also obtained an honours degree in engineering at London, and from 1914 to 1918 he was engaged on aircraft design at Shoreham Aerodrome, and upon experimental work, using a wind tunnel of his own design for various government departments. Some of his mathematical and experimental researches at this time formed the subject of two Reports and Memoranda of the Aeronautical Research Council issued in 1918 and 1919, both being concerned with flow in the rear of aerofoils at small angles of incidence. Professor Piercy's distinguished contribution to aeronautical education began in 1919, when he was appointed head of the Aeronautical Department, Queen Mary College, then the East London College. There, three years later, he was chiefly responsible for the introduction of aeronautics in the B.Sc. degree.

Following Dr. Lanchester's suggestion that trailing orifices of opposite hand existed at the extremities of an aerofoil, Professor Piercy directed experiments in the aeronautical laboratory with a 4ft wind tunnel, in order to establish a numerical analysis. This work was published in the *Proceedings* of the Royal Aeronautical Society in 1923, together with a paper dealing with a particular assumption of Prandtl's aerofoil theory. His later experimental work aimed at establishing a theory of two dimensional boundary layer flow and was the subject of another report of the A.R.C. in 1928.

The study of laminar flow wings was the object of later researches until 1944.

Professor Piercy was University of London Reader in Aeronautics from 1934 to 1949, and lecturer in aeronautics and fluid mechanics at Cambridge from 1939 to 1944. He served on many committees for aeronautical education and was a member of council of the Royal Aeronautical Society. Amongst his other publications were the well-known textbooks on aerodynamics, and many contributions to aeronautical literature by way of papers and articles.

Professor Piercy obtained his D.Sc. Eng. (Lond.) in 1920; he became a member of the Institution of Civil Engineers in 1936, a member of the Institution of Mechanical Engineers in 1934, and a Fellow of the Royal Aeronautical Society in 1928. Since 1949, Professor Piercy had been the University Professor of Aeronautical Engineering at Queen Mary College.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

SELF-CONTAINED ALTERNATOR AND AIR COOLER

SIR,—The description on page 28, January 2nd, of a water-cooled alternator for Luabo is noted. A reader not aware of the facts would, I feel, assume from your article that there was something new in the idea of mounting a water cooler above an electrical machine, whereas in actual fact it has been common practice to do so for many years, particularly for generating plant on board warships.

It is usual on such sets to take fairly elaborate precautions to protect the electrical machine from flooding in the event of a burst tube or other cooler leakage. In the case you illustrate the cooler appears to be mounted directly above the stator frame, and it would be interesting to know what, if any, provision is made to prevent flooding from the causes mentioned.

G. A. PICKETT

Bedford,
January 2nd.

[Although it is common practice in warships to mount a water cooler above an electrical machine, this arrangement is unusual in an industrial installation of the kind described. In this instance no provision was considered desirable to protect the machine from cooler failure. More elaborate precautions are usually taken on warships where there is a possibility of severe shock resulting in fractured cooler tubes.—ED., THE E.]

Steelworks Furnace Maintenance and Repair

Last month there was held in London another conference in the series organised by the steel industry in this country, to discuss the findings of the Productivity Team on Iron and Steel which visited the United States in 1951. *The main subject of this conference was the maintenance and repair of open hearth furnaces, and four papers dealing with practice in this country and overseas were presented and discussed.*

THE maintenance and repair of open hearth furnaces was discussed at a joint meeting of the Iron and Steel Institute's Engineers' Group with the Plant Engineering and Steelmaking Divisions of B.I.S.R.A. on January 21st. This conference was one of a number being organised in the industry to discuss the findings of the Productivity Report published last June. One of its principal conclusions was that less maintenance man-hours are expended in America, despite harder furnace driving, and repair times are shorter.

British practice was discussed at the morning session, with Mr. J. F. R. Jones (John Summers and Sons, Ltd.) in the chair ; overseas practice was discussed in the afternoon session with Dr. T. P. Colclough, C.B.E. (British Iron and Steel Federation), in the chair. The papers read during the morning session were : "Cold Metal Practice : Fixed 80 to 100-ton Furnaces," by J. E. Pluck, Steel, Peech and Tozer ; "Hot Metal Practice : 80-ton Fixed and 250-ton Tilting Furnaces," by S. G. Williams, Guest, Keen Baldwins Iron and Steel Company, Ltd.

The papers presented at the afternoon session were : "Repair and Maintenance of Open Hearth Furnaces in Germany," by Dr.-Ing. C. Kreutzer and Dr.-Ing. A. Mund, Maerz Ofenbau G.m.b.H., Krefeld, Germany, which was presented by Dr. Mund ; "Repair and Maintenance of Open Hearth Furnaces in U.S.A.", by R. W. Evans and I. S. Scott-Maxwell, Steel Company of Wales, Ltd.

Mr. J. E. Pluck confined his remarks chiefly to practice at the Templebrough melting shop at Steel, Peech and Tozer, where there are fourteen furnaces of 80-tons capacity, all recently converted from producer gas to oil fuel, and now in the process of being rebuilt one at a time to 100-tons capacity.

The intention was to work eleven furnaces throughout. As the plan was based on roof life, and roof life averaged twelve weeks (patched if necessary to attain the average), one furnace must go back into operation each week, whatever the duration of the repairs on the three currently down. The speaker laid emphasis on the fact that in planning major repairs very careful attention was given to examination after shut down, the length of the campaign and the last major repair history, which together enabled a forecast of the necessary repairs to be made.

Top repairs were carried out after twelve weeks (one roof life), and general repairs after a campaign (a checker life), which was usually two roof lives. In a top repair all the furnace above the sill and the slag (which was very solid) were removed. All the brickwork was then rebuilt. This normally took a week, which was sometimes exceeded because of the necessity of including some checker and uptake repairs, which in turn was a consequence of improved roof life on some furnaces. A general repair was similar to a top repair with the addition of checkers and flues. That is, the checkers were taken out and replaced, flues cleaned out, furnace roof, front and back walls, tap hole, bath banks, burner block ends, ramp roofs, uptakes and all the slag pockets were dismantled and rebuilt, and the slag pocket arches, bridge wall, and neck and checker arches given any necessary repair. The speaker described the detailed organisation of a general repair, which lasted two weeks. Warming up took three days after each kind of major repair, in both of which the men employed were :—

Dismantlers : three shifts of twelve men and one charge hand on each shift=thirty-nine men.

Bricklayers : three shifts of twelve bricklayers and thirteen labourers and a charge hand on each shift=seventy-eight men.

The hot repair gang of bricklayers employed for maintenance and repairs also relined ladles. Roof patching was often necessary after eight or nine weeks. If, towards the end of the campaign, the furnace was draughting badly, then a false flue was sometimes built through the checker wicket and through a manhole into the flue, thus slightly short circuiting the checkers. This could be effective on a pitch-creosote-fired furnace, and might give an extra week's production. Replacement of a full new main roof and front wall because of accident would take about three days. Repair due to bath breakout might take anything from two to ten days.

On the question of brick supplies, Mr. Pluck said that his works used an average of 214,000 per week, of which 144,000 were used on top and general repairs, and of these bricks, 75 per cent were unloaded direct on the furnace site. Rail-

Original Access Wicket in Regenerator

way wagons in this country were not suitable for pallet loading, and they did not use it. He thought that to make pallet loading practicable it would be necessary to have wagons with 6ft wide doorways, access from each end and room on the wagons for a fork lift truck to turn round.

Refractories consumption averaged 60 lb per ton of steel on furnaces with silica roofs ; 35 lb on all-basic furnaces.

Average roof life had improved over the last six years (see Table), with a slight check in 1947–

Roof Life at Steel, Peech and Tozer

Year	Actual Life		Rate of working (Casts/Weeks)
	Casts	Weeks	
1946	126	10·6	11·9
1947	114	9·7	11·8
1948	126	9·6	13·1
1949	129	9·7	13·3
1950	157	12·0	13·0
1951	185	13·6	13·6

1948, when the extended working week was introduced. The big increase in roof life in 1950, accompanied by a slight drop in the rate of working was mainly due to the beginning of trials with low-alumina silica bricks. The very marked improvement in 1951 was due to a number of factors, including super-duty bricks, teamwork, the use of roof pyrometers by the furnace crews, and a reduction in the number of special repairs.

Low-alumina bricks gave excellent results when used for full roofs, but proved uneconomic. They were now used profitably where there was most wear.

Mr. S. G. Williams, describing "Hot Metal Practice : 80-ton Fixed and 250-ton Tilting Furnaces," said that at the East Moors works they had five tilting and two fixed furnaces. The shop had been operating over the last three years at 87 per cent furnace availability, equal to the continuous production of six out of the seven furnaces. It was hoped to increase these figures to 93 per cent and 6·5 per cent respectively within the near future.

They did not employ a separate hot repairs crew, so careful scheduling was essential, as was good intelligence of the state of all furnaces and thorough records of previous repair. A three-monthly repair programme was laid down, and in order to ensure that bricklayers were not required for a hot repair at the same time as they were wanted on a general repair, the beginning of a general repair sometimes had to be delayed.

A factor which had contributed to increased campaign life was the use of bonded instead of ringed roofs, which took one shift longer to install, but had reduced patching and practically eliminated collapses. Another factor was the use of basic bricks at furnace ports, front and back linings, wing and side walls and uptakes to charging floor level. Possible heat loss, however, through 9in uptake linings, had determined a return to 14in thickness. Mr. Williams said in this connection that it was now possible to keep a continuous record for 6 hours of the air temperature and waste gas temperature and, if necessary, for 24 hours. He had found that checker temperature was a very poor guide to the air temperature, which optical pyrometers on the checkers had shown to differ by as much as 150 deg. to 200 deg. Cent. The use of basic brick with added protection from a 3in splay on front pillars to reduce mechanical wear, and extensive water cooling had cut down maintenance repairs on the front lining to one complete renewal during one campaign.

Other factors contributing to increased campaign life were : a B.R.I. gun, used for maintenance inside the furnace ; and checker blowing, which appeared to result in loss of air preheat temperature, taking a day or two to regain, but which made it possible to raise the bearer arches by 1ft, which had speeded up removal of the flue dust on rebuilding.

Except in extreme necessity, top repairs were not carried out at East Moors. There were two categories of general repair. The first included roof, linings and walls, uptakes, pulling slag and top courses of checkerwork, which took seven days from fuel-off to lighting warming gas pipes. The second repair was similar but complete checkers were added, and it took nine days from fuel-off to lighting the warming gas pipes.

There were sixty-five bricklayers and eighty-five helpers in the shop, of whom five masons and twenty helpers were on day work rebricking steel ladles, doors, chutes, &c. Allowing for sickness and holiday, there remained eighteen to twenty masons and twenty to twenty-two helpers per shift for nineteen shifts during the week. The works labouring force was called upon for all preparatory work, such as cutting down and general brick and slag removal. A weekly incentive bonus was paid to all masons and helpers based on the weekly production hours of all furnaces. On one general repair, not including work on checkers or uptakes, 1113 mason hours, 1430 helpers hours and 3161 navvy hours were booked, fuel-off to gas pipes lit, being four days, eight hours and fifteen minutes. Of the 3161 navvy hours in this instance 1877 (59 per cent) had been spent in the slag pockets. This emphasised the importance of speed in pulling off slag and preparing the slag pocket area for the bricklayers. This applied especially to fixed furnaces, as on the tilters shields could be inserted between the main body and the intermediate ports and gas pipes lit without detriment to men working below. Roofs were dropped by crane, and the charger knocked in the front wall. The debris was thrown on to the valve house floor (on tilting furnaces through the slag notches), whence it was removed by tractor shovels and wagons or dumper cars for removal and sorting.

Slag and debris from the slag pockets were removed by tractor shovels, as illustrated, for the access of which the slag pockets had been enlarged. Similarly, regenerator wickets had been enlarged to allow the jib of a mobile crane to enter with buckets for removing the old bricks and with a pallet for rebuilding.

Cardox explosives were used for breaking up large lumps of slag, and a method using sand floor and walls with stopper sleeves had been adopted for easier placing of the charges.

Once the bricklayers could get on the job, said Mr. Williams, it was very important to ensure an ample supply of easily accessible material, and unlike the previous speaker, he had not found that palletising offered particular difficulties. All bricks were unloaded on to pallets and taken by fork lift trucks to the appropriate storage bay, whence they were removed by the same means to positions beneath the hatches in the charging floor and conveyed by crane to the site. Palletised roof bricks were positioned on stands set in front of the furnace or on the main cross girders of the furnace superstructure. Lining bricks were moved by roller conveyors into the furnace. Quite apart from advantages of service to the bricklayers, palletising very substantially reduced breakages and chipping. A brick elevator (as illustrated herewith) was now being used for conveying bricks speedily from valve house floor to positions unattainable by fork trucks, such as regenerator chamber arches. It was also used for delivery of bricks direct to a furnace through the slag notches.

Finally, the speaker said that in initial warming up with coke oven or blast furnace gas pipes, the roof temperature was raised to 400 deg. Cent. within twelve hours. Liquid fuel was then introduced and the furnace gradually warmed to top heat twenty-four hours later. Pipes on to commencement of first charge was forty hours.

In the discussion following these two papers, Mr. R. A. M. Wright (Stewarts and Lloyds, Ltd.), gave particulars of some repair times at Corby. An ordinary general repair took three days seventeen and three-quarter hours tar off to coke oven gas flares in bath. This included new roof ramps, frontwall and checkers; repair of doghouses, monkey and wingwalls, and jack arches; cleaning out of runners, flues and slag pockets; and taphole cut out and relined. Another general repair, including in addition to rebricking and ramming in a new bottom, the rebuilding of one chamber arch and relining air uptakes and bulkheads, took seven days eight and a quarter hours. A third repair, similar to the second, but including both chamber arches, took six days twenty and a half hours.

The methods used to achieve these times included the accurate assessment of labour and materials required based on records and inspection; palletising and strategic placing of bricks; rapid cooling as soon as the taphole was dried up; dropping the roof by crane slings; use of light alloy roof centres; discharge of debris (while roof bricks were being laid) through a hole in the stage direct into trucks at valve pit floor level.

To enable easy slag removal dry ramps, covered over with 2in bars and insulated with old bricks and sand, had been built into the slag pockets. A 30ft by 10in square bloom inserted across a fulcrum made it possible to prise up and remove the slag and clean out the slag pockets in about twelve hours. Basic ends had led to a more friable slag. Checkers had been changed to 13½ by 6 by 3 (10½in flues), giving at least eighteen months' service and easy cleaning.

Shop layout in relation to furnace availability was touched on by several speakers. Mr. R. W. Evans suggested that there were marked advantages in a stage railway and ground charger system, as opposed to overhead chargers. With ground chargers it was possible to use overhead cranes without interfering with charging, and when one furnace was under repair the area round it could be made independent of the rest of the shop, so that the part of the railway track serving that furnace could be used entirely for brick movement.

Selection of refractories and furnace design were also commented on. In this connection Mr. Pluck stated that from a single uptake furnace at his works they were gaining information which promised improvements in roof life, and might lead to quicker repairs than with other kinds of furnace.

In the afternoon session, Dr. T. P. Colclough welcomed Dr. A. Mund, who presented a paper by himself and Dr.-Ing. G. Kreutzer. This paper reviewed the open hearth process in Western Germany, where it accounted for 52·5 per cent of the steel output. Little reference was made to the various kinds of repairs or the use of machinery, which the age and layout of most German works made it impossible to use. It had therefore been necessary instead to develop the highest possible durability of the furnaces and thus reduce the number and duration of repairs. In this way, a degree of utilisation, at least as high as in America, and sometimes even higher, could be achieved.

After discussing furnace design, firing arrangements and the construction of checker chambers and flues, Dr. Mund turned to roof life and said that all-basic furnaces and furnaces with supported or suspended roofs now accounted for 30 per cent of the total, and this proportion was growing. It included coke oven gas, mixed gas and tilting furnaces. Exceptionally long roof lives had been obtained. In one large coke oven gas furnace with additional oil firing, the roof lasted approximately 1750 heats, in which the furnace produced 192,000 tons of steel. In another case, with a coal-dust carburetted 60-ton coke oven gas furnace, more than 100,000 tons of steel had been produced with one roof lining. Dr. Mund added that at the end of December, 1952, the roof of a 35-ton coke gas furnace had reached a life of 4000 heats.

The so-called box-form of roof construction was giving good results. In this design, said Dr. Mund, single courses between the lateral ribs were subdivided by the insertion of longitudinal ribs into any desired number of "boxes." This provided a further bracing of the whole roof and enabled any single prematurely worn places to be secured by filling up the affected boxes with filler bricks.

The speaker said that economic success had resulted from the use of oxygen in the enrichment of air to 23 per cent in gas producers; in speeding up scrap melting by enrichment of combustion air to 23 per cent to 24 per cent; in decarburising by lance in certain cases, such as the production of very low carbon steels; and in desiliconising stahleisen, by oxygen injection in the ladle.

Mr. I. S. Scott-Maxwell (Steel Company of Wales, Ltd.), a member of the productivity team, introduced the paper by Mr. R. W. Evans and himself. He drew attention to the statistics for basic open hearth steel making for 1950, given in the Productivity Report.

There were several differences between the two countries which affected furnace repairs. In the much larger American steelworks, large concentrations of labour could be brought to bear, and there was more space available in and around the plant for mechanical aids to quick repairs. Furnaces were larger, averaging 130 tons tapping capacity, compared with 90 tons in the U.K. 75 per cent of American open hearths were fixed, operating on the hot metal process.

The number of taps per week did not differ materially from British practice, but because of the greater tonnage tapped and the higher availability of the furnaces, the productivity per unit of plant averaged 57 per cent greater than in Britain. Much of this was due to very high furnace availability in American melting shops, the national average being 91 per cent, while some works attained 96 per cent to 97 per cent year in and year out. Such results meant that any one furnace was only off production for a total of about two weeks in a full year. The average availability of the three shops at Sparrow's Point was 97·5 per cent or 50·7 weeks out of fifty-two. Part of the reason for the low British figure was the practice of having a "spare" furnace not normally manned on which repairs were carried out at a slower pace.

The Americans had the advantage of rich natural fuels and consistent raw materials. In matters of design a continuous effort was made to attain higher production from existing plants. For example, larger uptakes reduced gas velocities, despite higher volumes due to hard driving. By the introduction of wider aperture checkers and larger volume slag pockets, checkers lives could now be measured in years rather than months.

Roof life was "no longer a headache" to American steelmakers, because roof patching had been brought to a fine art. A length of

Tractor Entering Slag Pocket

Brick Conveyor to Top of Regenerator Arch

crown 50ft long by 3ft wide could be replaced in four hours. Heat input was not limited, nor charging carried out carefully for the sake of roof life. Co-operative planning between all departments was the secret of success. The unifying force was a real desire by everyone to keep all the furnaces working for the maximum number of hours in the year.

Some of the steps that could be taken in Britain to improve furnace availability were :

(*a*) All shops to work more than nineteen shifts per week, if possible twenty-one shifts.

(*b*) The idea of " spare " furnaces should be forgotten and all such furnaces manned when raw materials are available.

(*c*) Quick patching technique of roof repairs to be adopted, together with higher operating temperatures.

(*d*) Better scrap preparation.

(*e*) Development of mechanical aids to quicker repairs suitable to British melting shops, such as light alloy roof centres, hanging platforms, brick elevators, palletisation, &c.

(*f*) Quicker methods of slag removal.

(*g*) Heavier furnace steelwork, additional water cooling, quicker methods of wrecking the furnace.

In the U.S.A. a top repair, including complete roof, front and back linings, uptakes and blocks could be carried out in twenty-one hours fuel-off to fuel-on. Such fast repairs were achieved by concentrating a large labour force on the job and ensuring a high degree of detailed planning before the work began.

At Sparrow's Point, for example, a tentative schedule was made for six months and each of the twenty-eight furnaces appeared twice, either for a general or a quick top repair. A general repair took about four days and a quick roof repair about twenty-five hours. Such repair times could only be achieved after long practice and the development of time-saving mechanical aids which fitted into the normal working of the shop.

The speaker described the organisation of typical furnace wrecking and rebuilding operations. When the repair was completed, furnaces were brought up to temperature relatively quickly. After a general repair, charging would begin about fifteen hours after first lighting up and the first tap some twenty-seven hours after.

At the Lachawanna plant of Bethlehem Steel Corporation, by paying close attention to heating up rates, the time to tap after repairs had been reduced to an average, for a year, of twenty-two hours, with an occasion when sixteen and a half hours was achieved. Initial warming up was started as soon as top repairs were complete, and before bottom repairs were finished. Up to 600 deg. Fah. great care was taken, above this the heating rate was increased rapidly.

In the ensuing discussion, Mr. G. R. Bashforth (Round Oak Steel Works, Ltd.), referred to the effect on availability of the layout of old plant. At his works the old melting shop with two 90-ton tilting and five 60-ton fixed furnaces, an availability of 81·2 per cent had been obtained. In their new plant they had had some early troubles (which the speaker described) during the first two years of operation, but the schedule for 1952–3 aimed at an average furnace availability of 91·8 per cent, with eight general repairs of eleven days and six top repairs (not including regenerators) of nine days. Although the adoption of the new schedule and improved methods was recent, so far out of 11,520 furnace-hours available they had actually operated 10,416 furnace-hours.

Mr. R. Wogin (Appleby-Frodingham Steel Company), commented that the difference between oil-fired and gas-fired furnaces was a fundamental reason why British repair methods and results must always fall short of American. He thought that where a British gas-fired furnace had a ten-day repair, compared with four days, the best at Sparrow's Point, four days of the difference lay in the design of the furnace. There was 25 per cent to 50 per cent extra brickwork to cool down, and two slag pockets instead of only one. Even so, the latest furnace repair at the speaker's works, including ramming in a new bottom, taking 140 tons of slag out of the slag pockets, replacing all air checkers and redesigning the block, was completed in five days one hour from gas off to beginning to warm up.

Mr. A. Provis (Guest, Keen Baldwins Iron and Steel Company, Ltd.) said that factors which had contributed to increased furnace life per campaign were the use of basic bricks and zebra roofs ; the use of super duty bricks ; spray guns used by the first helper to repair skewback bricks, tapholes and so on, and for inside furnace maintenance; soot blowers in the furnace and rigorous flue cleaning ; continuous flow of materials for repairs ; and a minimum amount of piping, beams, bars and steelwork of all descriptions to cause interference on top of the furnace.

Mr. Provis thought that production men at the conference had to see that the efforts of the engineers were backed up " by regarding minutes saved now as more valuable than hours later on, by the education of the labour force to a sense of urgency, and by a tendency towards a slight over-manning of maintenance forces. A 1 per cent over-manning is more economic than a 0·26 per cent under-manning in relation to greater productivity figures."

Modernised Oil Engine Works

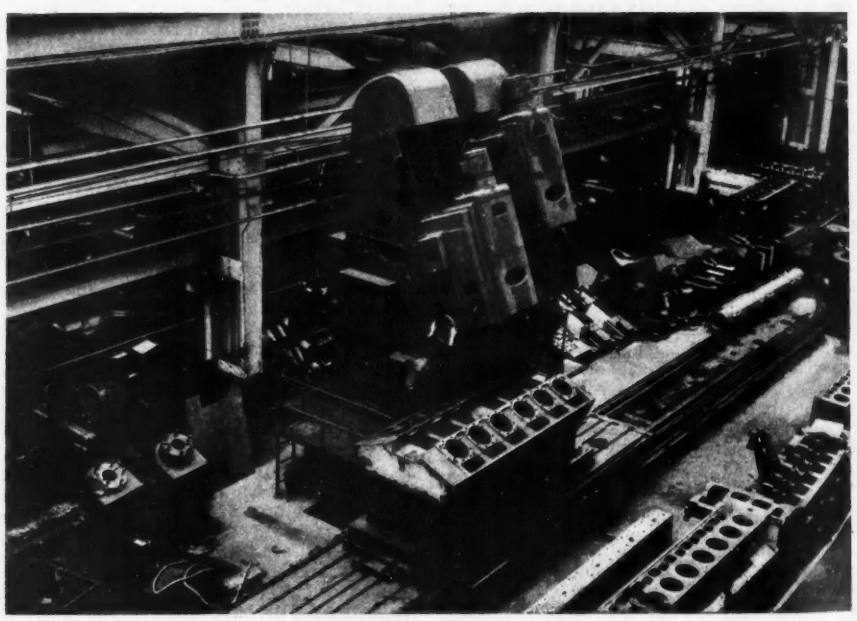
During the years since the end of the war the Hazel Grove Works of Mirrlees, Bickerton and Day, Ltd., has been steadily re-equipped with modern machine tools. More recently additional floor space has been added and machines moved to conform with a plan to produce engines of two cylinder sizes.

INTERNATIONAL competition and the trend of world trade impose economic conditions which make imperative the careful study of methods of manufacture and the rationalisation of products. The rising cost of materials and labour and shorter working hours have to be countered by improvements in the overall planning of production and some degree of standardisation. Plans to achieve this are dependent upon the range and size of engines built and whether they can be built on a batch basis. For some considerable time Mirrlees, Bickerton and Day, Ltd., has been engaged in reorganising its factory at Hazel Grove, Stockport, Cheshire, and at the invitation of the company we were able to pay a visit to inspect the factory and to see something of the new layout of the machine shops and the completed extensions.

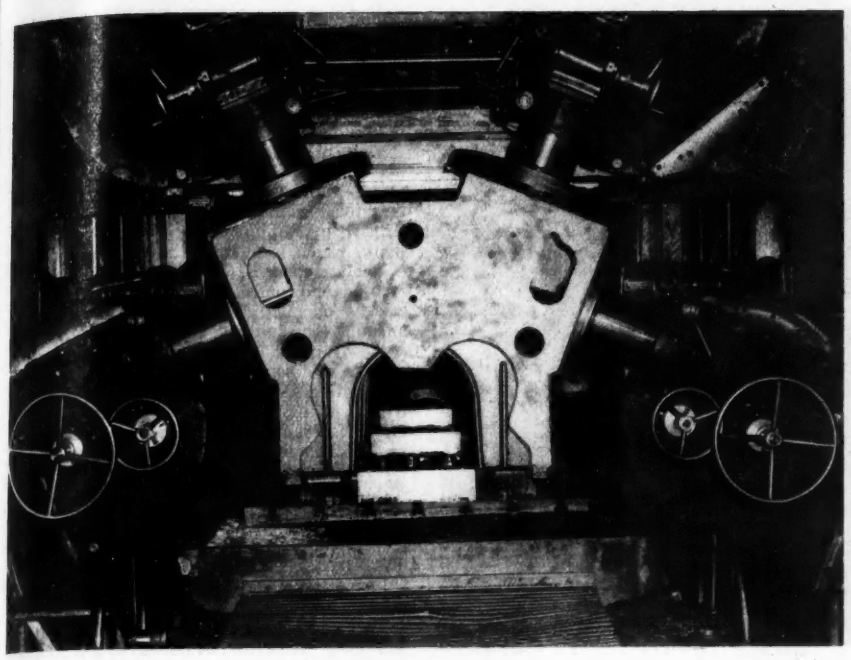
It was in 1897 that the company completed its first diesel engine, which is now in the Science Museum, South Kensington, and was a single-cylinder, four-cycle, air-injection unit having a bore and stroke of 300mm by 460mm, and developing 20 b.h.p. at 200 r.p.m. Six years later, H.M.S. " Dreadnought " was equipped with auxiliary diesel engines which developed 160 b.h.p. at 400 r.p.m., and they were the first oil engines to be used in a naval vessel. The actual factory at Hazel Grove did not come into being until 1908, when Mr. Day, having decided that another factory was needed, acquired the present site and formed the new company of Mirrlees, Bickerton and Day, Ltd. He also had the foresight to provide for future expansion and purchased additional acreage, after the first world war.

The general arrangement of the factory and the recent extensions were planned to assist in carrying out the principle of flow production and at the same time to allow for further expansion in a northerly direction. Over one-third of the floor area, which is now approximately 300,000 square feet, has been added since the war, and during that period nearly all the machine tools and equipment have been replaced. The flow of the rough components is carefully controlled through the various machining and other operations in the general, light and heavy machine shops, the stores, the sub-assembly bay, the main assembly bay and so finally to the test beds. The finished components pass to the main stores for issue to the sub-assembly section, and the main engine components pass directly to the main assembly.

For handling both small and heavy components the factory is well served by overhead cranes, which are mounted in practically every bay. To avoid encroaching upon or limiting the craneage area, fixed equipment has been sited, as far as possible, between stanchions, and the heavy machines have been allocated to the bays having the most headroom so that large parts can be handled easily. Manhandling of components from machine to machine has been largely eliminated by fitting electrically operated jib cranes to stanchions, so that movement between operations is expedited. Again, physical fatigue in the handling of engine parts is kept to a minimum by employing the pallet and stillage system in association with a large fleet of battery-operated hand and fork lift trucks. Roller conveyor tracks are provided for the main assembly of the smaller engines, while the larger engines are built in the main bay. As part of



Asquith Two-Head Angle Borer



Four Head Plano-miller

the flow plan and to assist in the rapid assembly of an engine, the various components for individual sub-assemblies are issued by the stores in steel containers ready to be shipped to the assembly bay or roller track.

As already mentioned, most of the machine tools have been renewed since 1946 and extensive use is made of pneumatic tools. Air-operated jigs and fixtures have also been designed and employed for various operations where the expense is justified by batch size. In the light machine shop is a battery of David Brown gear hobbing machines and a gear shaver and among other equipment is included Landis and Churchill grinders and Cincinnati and Archdale millers. The turret lathe department is well equipped with Herbert, Ward, B.S.A. and Acme-Gridley machines, and in the general machine shop are various vertical boring and drilling machines, a George Fischer profiling machine for machining the special through bolts required for the "K" engines. It was of interest to note the arrangement of one Churchill-Fay and two Alfing machines in which an aluminium piston casting can be rough turned, gudgeon pin holes rough bored and finished, and the whole piston machine finished in about twenty-five minutes.

Among the special machines in the heavy machine shop is the Asquith inclined, twin-head, cylinder block borer, seen in our illustration, which has been specially designed and built to meet the production requirements of Mirrlees, Bickerton and Day, Ltd. This machine, which accommodates both in-line and vee pattern engines, has a high degree of accuracy, and bores the main housing for cylinder liners at an average rate of about ninety minutes per cylinder. There are four Plano-milling machines, including a Gildemeister, and one with four heads by Kendall and Gent, which our photograph shows in operation, each cutter having twenty tools specially set for progressive cutting. Time is saved and greater accuracy is achieved in connection with the fitting of main bearings by the Alfing horizontal fine borer, which bores each bearing simultaneously and employs three tools, two for rough cuts and one for finishing. A Richards pinning machine turns the crankshaft crankpin to an accuracy of 0·0005in in one operation, and an Oldfield and Schofield centre turning lathe carries out the journal roughing operation.

A very careful check is kept on the accuracy of the machine tools and on the finished parts, and for this purpose there is a well-equipped standards room. In the room is a Cook Troughton and Simm's optical dividing instrument having an accuracy of one-fiftieth of a minute, there are Sigma comparators accurate to 0·0001in, and a microptic measuring machine capable of measuring length or diameter up to 8in to within 0·00005in. A Tomlinson surface finish recorder is installed and also a Newall length gauge having a capacity up to 4ft and an accuracy of 0·00001in. A Hilger Watts comparator having a magnification of ×25 checks the accuracy of thread profiles.

The testing of engines is the end of the production line, and to ensure that no bottleneck occurs at this point the testing bay has been designed to accommodate thirty test beds. Two beds have yet to be built and two are of a size sufficient to take the "K.V.S.12" engine, which is the largest engine of the range built by the company. The testing bay is fully equipped with Heenan and Froude dynamometers. A large proportion of the electrical needs of the factory are met by two of the company's diesel engines, a Mk. "T.V.12," a twelve-cylinder vee engine, and a "J.S.6" a six-cylinder in-line turbo-charged engine, each of which develops 750 b.h.p. at 600 r.p.m., and a total of 900kW. Space heating for about 6,000,000 cubic feet is provided by two Lancashire boilers, and in the pump house are eight single-stage centrifugal pumps, and Heenan and Froude coolers for cooling 3000 gallons of water per minute from 135 deg. to 90 deg. Fah. The installation is of sufficient capacity to deal with a total of 13,000 b.h.p., which may be on test at any one time. When fully operational on the new engines, it is anticipated that the factory will be able to complete engines at an overall rate of 2500 b.h.p. per day.

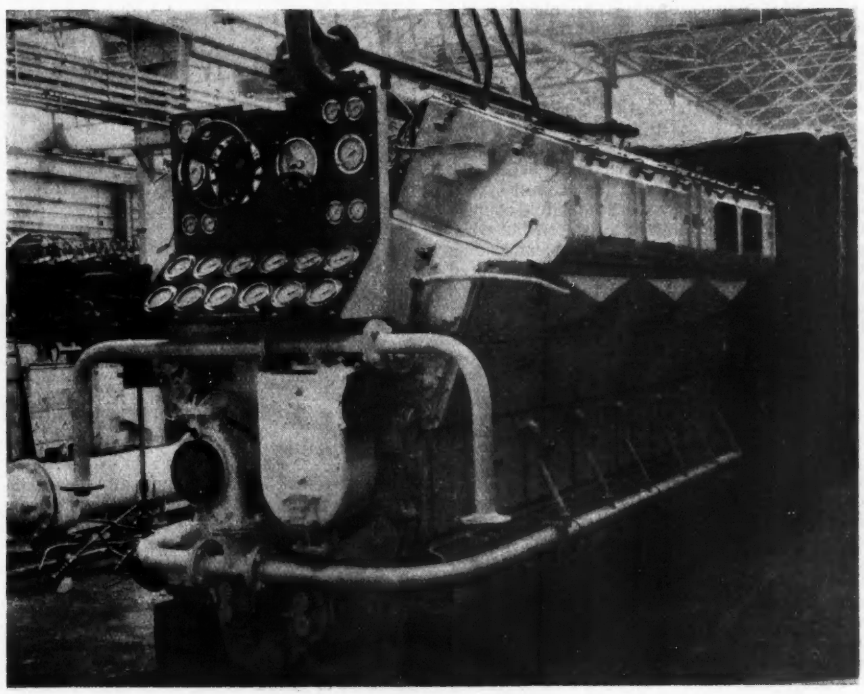
Range of Engines

As part of the scheme of rationalisation the company decided to concentrate on the production of two four-stroke, single-acting, airless-injection engines, namely Mks. "J" and "K." Although built in two cylinder sizes only, the power range of the "J" and "K" models is more than twice that of the previous maximum output, so that the potential market is considerably extended. Both engines are available as vertical in-line and Vee engines, and are either naturally aspirated or pressure charged or high-pressure charged with air intercooling. The aim of the design has been to produce a compact power unit having robust construction and good accessibility while maintaining low piston speeds.

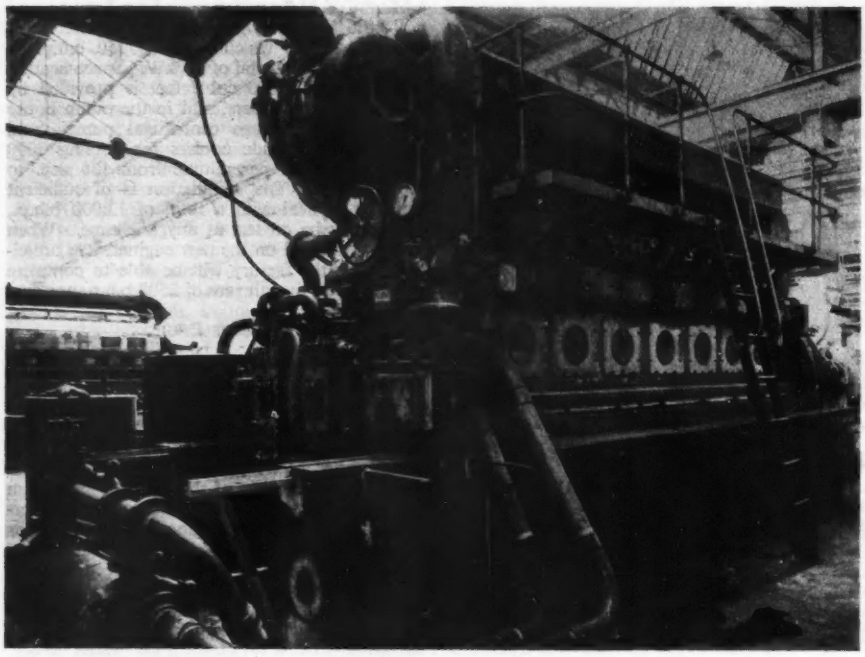
All the "J" and "JV" engines, which are the smaller pattern, have cylinders of 9¾in bore by 10½in stroke, and are built in a number of sizes from three to sixteen cylinders and cover a range of power from 165 to 2500 b.h.p. This series of engines, one of which we illustrate, has been in production for some time, and a prototype of the largest size built, the "J.V.S.S.16," a sixteen-cylinder, vee, pressure-charged engine, was shown in 1951 at the Exhibition of Industrial Power at the Kelvin Hall, Glasgow. A description of this engine appeared in The Engineer of June 22, 1951.

The Mk. "K" and "KV" engines are built in sizes from five to twelve cylinders, having a bore and stroke of 15in by 18in, respectively, and the engines, which are suitable for speeds up to 450 r.p.m., cover a power range of 485 to 3000 b.h.p. Our photograph overleaf shows a Mk. "KDS 7" engine on test.

Cast iron is largely employed in the construction of the engine, fine quality material being



"J.V. 12" Engine



"KDS7" Engine on Test

used for the bedplate, column, cylinder casing, cylinder liners, piston rings and pistons. The pistons are oil cooled and have four pressure rings and two scraper rings, while the cylinder liners, which have no cutaways for valve heads or connecting-rod clearance, are fixed by the top flange and free to expand downwards. Steel stampings of H section form the connecting-rods, which have white-metal-lined big-end bearings and small-end bearings of phosphor-bronze. The crankshaft is of "40" carbon steel normalised to B.S. En. 8, and is carried in steel-backed while metal bearings. A high degree of cylinder scavenging and a maximum volumetric efficiency has been obtained by adopting a four-valve cylinder head, the valves being operated by rocker arms and push rods actuated by a high-tensile steel camshaft with cam sleeves of "Monikrom." The camshaft bearings, which are in halves and are removable without disturbing the shaft, are pressure lubricated, while the cams and cam rollers are splash lubricated.

Individual pumps, operated by roller tappets, are fitted above the camshaft and the pipes from pump to the injector, which is placed centrally between the four valves, are of equal length. Pressure charging is on the Buchi principle and, when fitted, the turbo-charger is a single-stage, axial-flow exhaust gas turbine driving a centrifugal air compressor. The turbine casings incorporate water-cooling jackets. When the engine is normally aspirated the exhaust system includes a water-cooled exhaust manifold coupled to an outlet pipe leading to a silencer, but when pressure charged the multi-pipe system leading to the turbo-charger is employed. Engine speed is controlled by a centrifugal pattern governor, and oil is supplied to the forced lubrication system by a gear pump.

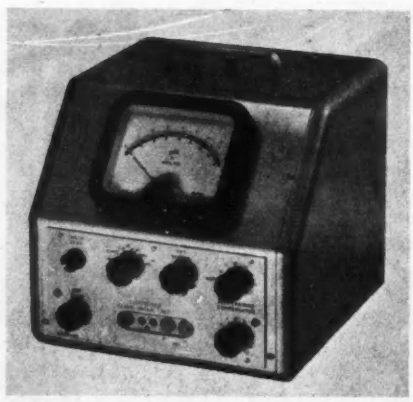
A Portable pH Meter and Millivoltmeter

THE direct-reading, portable pH meter, which was introduced by W. G. Pye and Co., Ltd., Cambridge, in 1951 and was exhibited at the Physical Society's Exhibition last year, has now been modified to suit a greater variety of applications. In its new form the instrument (illustrated herewith) incorporates both manual and automatic temperature compensation and it has a range of electrode parts whereby different assemblies can be made up to cope with diverse measuring conditions.

Briefly, the instrument is a direct-reading millivoltmeter with a scale graduated to indicate pH or mV×100, and it enables pH values of liquids to be measured by comparison with the pH values of specified buffer solutions.

The procedure is to adjust the zero setting of the instrument, place the selected electrode assembly in a beaker containing the buffer solution (made up from the buffer tablets supplied) and then to adjust the "Set Buffer" knob until the instrument pointer indicates the stated pH value of the buffer solution. Then the "Set Buffer" knob can be clamped and the instrument is ready to be used for pH measurement without reference to the buffer solution for the rest of the day. Zero deviation is stated to be not more than ±0·02 pH and the setting can be confirmed at any time by using the "Check Zero" button and "Set Zero" knob. Full stability is attained within about fifteen minutes of switching on the set.

The electrodes supplied with the set consist of a small-bulb glass electrode, covering the full range of 0–14 pH, and a calomel reference elec-



Portable pH Meter and Millivoltmeter

trode with a wick-type liquid junction. A special sealing arrangement at the top of the reference electrode prevents creeping of the potassium chloride solution and allows the interior element to be withdrawn when refilling with the potassium chloride solution is necessary.

To suit various requirements the electrodes can be arranged to form three different assemblies. First, the electrodes can be protected by a polythene sheath having a platinum resistance thermometer sealed in its lower end for automatic temperature compensation. Secondly, where cleaning is an important requirement (for example, in measurements involving adhesive or viscous materials) an open assembly can be used: the electrodes, together with a resistance thermometer for automatic temperature compensation, are clipped into a small holder. Thirdly, there is a micro-assembly for use when small quantities of liquid are to be measured.

Two pH ranges (0–8 and 6–14) and two mV ranges (0–800 and 600–1400) are provided, with a single selector switch for all. Negative feedback is used in the electronic circuit to attain linearity and the sensitivity, which is unaffected by mains variations or valve changes, is 100 μA/pH. External recorder and controller circuits up to 10,000 ohms can be operated from the instrument without affecting the sensitivity; for this purpose a jack socket is provided at the back of the meter casing. A semi-electrometer valve, operated under conditions which ensure low grid current, is used in the input stage of the meter and it is possible, therefore, to use electrodes having up to 500 megohms resistance without incurring errors of more than 0·02 pH.

Automatic and manual temperature compensation is provided. Manual compensation is effected through coarse and fine controls. The first point on the coarse control knob is marked "Auto" and adapts the circuit for use with either of the resistance thermometers provided with the electrode kit.

The instrument is mains operated (110 or 200–250V, 50 c/s) and is housed in a sheet metal casing, 11½in wide by 12in deep by 11in high. A hinged lid at the top of the casing gives access to a compartment which houses the accessory box containing the pH electrodes and accessories.

Electrification of the Late Sao Paulo Railway, Brazil

THE first stage of the electrification of the Estrada de Ferro Santos a Jundiai (late Sao Paulo Railway) was the subject of a paper presented by Mr. R. J. B. Chatterton and Mr. D. H. Rooney before the Institution of Electrical Engineers yesterday. In this paper the authors gave a short history of railway development in Brazil and described the electrification at 3000V d.c., of 118 single track miles of main lines and sidings between Jundiai and Mooca in the State of Sao Paulo.

The authors gave three main reasons for the electrification: first, the increase in passenger density as indicated by the fact that passenger traffic alone increased by 22 per cent between 1946 and 1949; secondly, the difficulty of obtaining imported coal and the rising cost thereof; and thirdly, the increase in the hydro-electric resources of the State of Sao Paulo, where the power generated increased by about 140 per cent between 1940 and 1948.

Discussing the results of operations for 1951 and part of 1950, after less than two years of electrification, the authors pointed out that considerable economies had already been achieved in operating and maintenance costs, particularly in fuel consumption, operating staff and repair of locomotives. A diagram reproduced in the paper showed that the cost of fuel and electrical energy, expressed as a percentage of total earnings, fell from 18·5 per cent in 1949 to 15 per cent in 1950 and about 12 per cent in 1951, despite an increase of 44 per cent in the price of coal. Another diagram showed that the traffic expressed in millions of ton-miles increased from just over 1000 in 1950 to about 1125 in 1951 during the first full year of electrified operation. Considering passenger traffic specifically, the authors pointed out that the increase in 1950–51 was 20 per cent compared with the returns for 1949.

NYLON BEARING BUSHES.—Small bearing bushes of nylon are now being moulded at the Witton Moulded Insulation Works of the General Electric Company, Ltd., for the wringers of washing machines which were formerly made of metal. We are informed that this change was made because the necessary lubrication by oil of metal bearings is not regarded with favour on a washing machine, since detergents soon disperse the oil. The nylon bushes are effectively lubricated by water.

American Gas Turbines in 1952

(By our American Correspondent)

THE design of industrial gas turbines under construction in the past year by the two American manufacturers—General Electric and Westinghouse—has continued to follow a pattern stressing simplicity and compactness of plant, and offering only modest thermal efficiencies. Due to the reliable and successful operation of their initial units, both companies have recently received considerable orders for gas turbines to be used as prime movers in both power stations and in natural gas pumping stations. Thus, in the latter field, the General Electric Company is now manufacturing over forty of its 5000 h.p. gas turbine-driven centrifugal compressor pumping plants. In the field of electric power generation, with the exception of the 15MW unit being built by Westinghouse for the Public Service Company of Oklahoma, all American plant at present under construction lies within a capacity range of 3·5MW to 5MW. Certain data relative to the "standardised" industrial gas turbine plants which are being offered by the two main builders have been tabulated below:

Manufacturer	General Electric			Westinghouse			
Cycle	Simple, open, single shaft	Regenerative, open, 2 shaft	Regenerative, intercooled, open, 2 shaft	Simple, open, single shaft	Regenerative, open, 2 shaft	Simple, open, single shaft	Regenerative, intercooled, open, 2 shaft
Rating: kW	3,500	3,730	5,000	1,250	3,500	5,000	15,000
h.p.	4,690	5,000	6,700	1,675	4,700	6,700	20,000
Thermal efficiency, per cent	14·9	23·5	26·4	15·9	22·5	18·9	26·5
Heat input rate, B.Th.U. per kWh	22,900	14,500	12,900	21,500	15,200	18,100	12,900
Turbine inlet temperature, deg. Fah.	1,400	1,450	1,500	1,350	1,350	1,350	1,350
Pressure ratio	6·0	5·5	9·0	4·6	4·0	6·0	8·0
Weight, lb	86,000	370,000	310,000	38,000	200,000	93,800	700,000

The above data are based on an 80 deg. Fah. ambient temperature and an altitude of 1000ft above sea level. Both the heat input rate and the thermal efficiency are based on the h.c.v. of residual ("Bunker C") fuel oil.

The largest industrial gas turbine production order so far received by an American manufacturer was the order placed with the General Electric Company by the El Paso Natural Gas Company for twenty-eight 5000 h.p. natural gas pumping plants, which are expected to be delivered by the end of this year. There can be no doubt that this application is an ideal one for the gas turbine—gas turbine-driven centrifugal compressors are complete, self-sustaining power plants in themselves, taking fuel directly from the pipeline and requiring little or no water and no outside electric power. As most of the functions and protective systems of these gas turbines are entirely automatic, few operating personnel are required. At the temperatures and speeds at which these gas turbines are operated, they have proved suitable for the continuous heavy-duty operation required on gas pipeline pumping service when burning natural gas. Their reliability and maintenance in service is already proving as good as or better than those of steam turbines.

The turbine is a two-shaft adjustable speed machine having a thermal efficiency, when using a regenerator, of 25 per cent, based on the l.c.v. of the gas. The accompanying illustration shows a cut-away view of the gas turbine. The plant is started with gas pressure from the pipeline expanding to atmosphere through an expansion starting turbine. The schematic flow diagram of the turbine is reproduced here. Adjustable nozzles, which are automatically controlled by the governor, have been placed between the h.p. and the l.p. turbines. Their function is to permit a transfer of the heat energy available between the h.p. and l.p. turbines.

Based on experience gained in the operation of an initial 1850 h.p. gas-turbine-driven centrifugal compressor, the Westinghouse Electric Corporation is now building a 5000 h.p., two-shaft power plant designed as a prime mover for natural gas pumping service. A two-stage h.p. turbine drives an eleven-stage axial compressor, having a compression ratio of 4·0, at 6200 r.p.m. The compressor discharge passes through a regenerator and six combustors, entering the turbine at 1350 deg. Fah. The single-stage, load-driving l.p. turbine has a rated full-load speed of 6500 r.p.m.

During the past year a number of General Electric 5000kW gas turbine electric generating sets were delivered to power companies in New England for operation on oil fuel. These two-shaft units operate on an open, compound regenerative cycle, making use of intercooling between the two axial-flow compressors. The two-stage h.p. and the single-stage l.p. turbines have rated speeds of 8700 and 7200 r.p.m. respectively, and power is taken off at 3600 r.p.m. The thermal efficiency of these units, based on the h.c.v. of the oil fuel has been in the region of 26 per cent.

A number of simple, open-cycle General Electric 3500kW single-shaft gas turbine electric generating units are also now being installed for both natural gas and oil burning service. A fifteen-stage axial-flow compressor is driven by the two-stage turbine at 6700 r.p.m., the load drive being taken off at 3600 r.p.m. These units have been found to develop thermal efficiencies of 15 to 18 per cent.

Gas Turbine Electric Locomotives

It may be recalled that the first American gas turbine electric locomotive was built by the General Electric Company and entered experimental service in November, 1948. This eight-axle unit had a fully loaded weight of 66,500 lb per axle, a rated input to the traction generators of 4500 h.p. and a continuous tractive effort of 77,800 lb at 18·2 m.p.h. A total of 105,732 miles has now been covered on test with the power plant operating for 5325 hours.

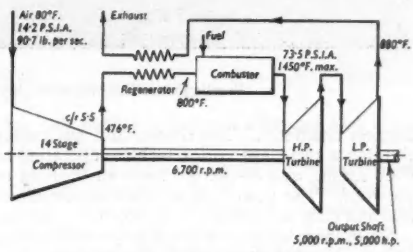
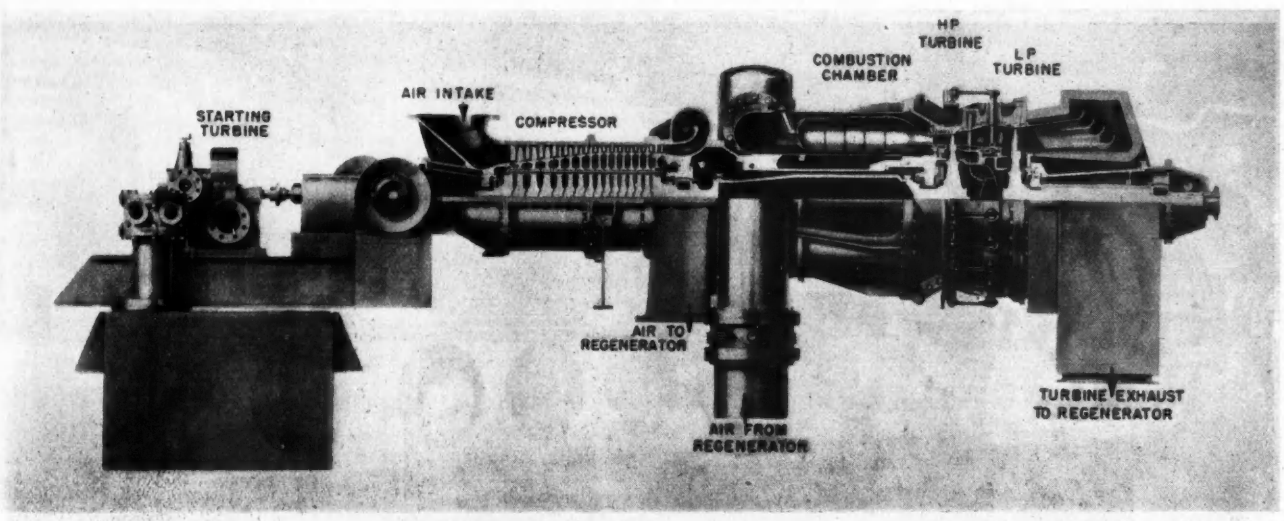
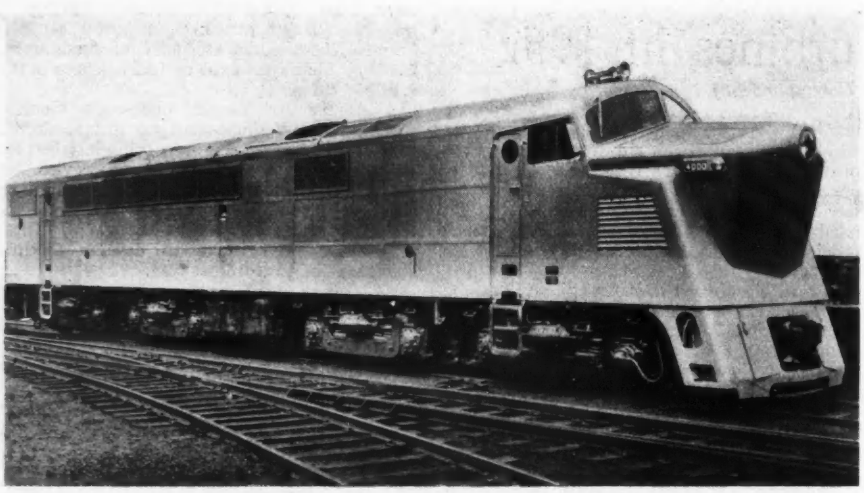


Diagram of 5000 h.p. Regenerative Cycle Gas Turbine

An order was placed by the Union Pacific in 1951 for ten gas turbine electric locomotives to be similar to the first locomotive, and in placing this order the railway requested a number of changes in addition to those proposed by the builder. The primary request was for an increase in fuel capacity from 6600 to 8000 U.S. gallons of heavy fuel. The builder was able to provide a capacity of 7200 U.S. gallons and still meet the load limit of 71,800 lb per axle set by the railway. This capacity enables the locomotive to handle runs of 300 to 400 miles without intermediate refuelling. The weight of the unit has been increased to 550,000 lb. Using 40in wheels instead of the original 42in ones, the continuous tractive effort has been increased to 105,000 lb at 12·9 m.p.h. The rated maximum speed has been reduced from 69·3 to 65 m.p.h. The 4500 h.p. single-shaft, open-cycle gas turbine power plant is at the forward end of the engine-room. It has a fifteen-stage, axial-flow compressor with an inlet air silencer, discharging into six com-



General Electric 5000 h.p. Gas Turbine for Natural Gas Pumping Service



Westinghouse-Baldwin 4000 h.p. Gas Turbine Electric Locomotive

bustion chambers. The combustion gas passes through a two-stage vortex turbine, operating at 6900 r.p.m., and discharges from an opening in the roof. The power plant is started on diesel fuel and runs on residual (" Bunker C ") fuel oil.

Six of these locomotives were delivered between February and August, 1952. According to the maker, their train handling abilities have proved better than those of the pilot locomotive. There has been little difficulty in train starting. The first locomotive delivered was slippery on the front bogie. This was overcome by ballasting and by the addition of a manually operated power reduction switch in the circuit supplying the front pair of traction motors. The locomotives are said to be still somewhat sensitive to poor rail conditions. Practically all of the operation to date has been on a 175-mile mountain division between Green River, Wyoming, and Ogden, Utah. The elevation varies from approximately 4300ft to 7200ft above sea level. The locomotives handle trains weighing up to 4500 tons.

The Westinghouse-Baldwin experimental 4000 h.p. gas turbine-electric locomotive of the Westinghouse Electric Corporation, which first entered service in May, 1950, has been subjected to further extensive test operation during the past year. The eight-axle, single-unit locomotive is shown in the illustration above. It weighs 222 tons and is powered by two 2000 h.p., open-cycle, single-shaft turbines mounted in a " side-by-side " arrangement. One turbine exhausts through a waste heat boiler ; the other directly through the roof. Both turbines are of aircraft design, using an axial-flow compressor with " can type " combustors. This arrangement has the benefit of simplicity and flexibility, but it eliminates the possibility of using a regenerator and thus restricts the cycle efficiency obtainable. Various heavy fuel oils have been tried in this locomotive, and it is being used to some extent as a fuel laboratory to help determine and establish the necessary specifications for heavy gas turbine fuel oil. A representative of the company has stated that the only fuel specification established to date has been a low-sulphur residual with a maximum of 0·5 per cent ash, with the vanadium-pentoxide content of the ash not exceeding 15 per cent.

The principal weights, dimensions and ratings of the locomotive are tabulated below :

Main Particulars of 4000 *h.p. Locomotive*

Overall length	77ft 10in
Width over cab	10ft 2¼in
Maximum height	15ft
Total wheelbase	62ft 9in
Rigid wheelbase	9ft
Continuous tractive effort	52,800 lb at 23 m.p.h.
Maximum speed	100 m.p.h.
Total weight, loaded	494,000 lb
Fuel capacity	4000 U.S. gallons
Water capacity	2300 U.S. gallons

The locomotive is equipped with running gear which consists of four identical two-axle bogies, each of which can move laterally under the cab to negotiate curves. A roller carriage is attached to each bogie by a centre pin allowing the usual swivel action of the bogie. The cab rests on the rollers of the four carriages, thus permitting lateral motion. The lateral motion of the end bogie is restrained by leaf springs, while the two middle bogies permit free lateral motion, Early operation showed that the springs on the end bogies required increased stiffness to prevent the restraining springs on these bogies becoming " solid " on sharp curves. Favourable comment has been received on the smooth riding and good tracking features of the locomotive, and, except for the one change in lateral spring stiffness, no troubles with the running gear have been experienced.

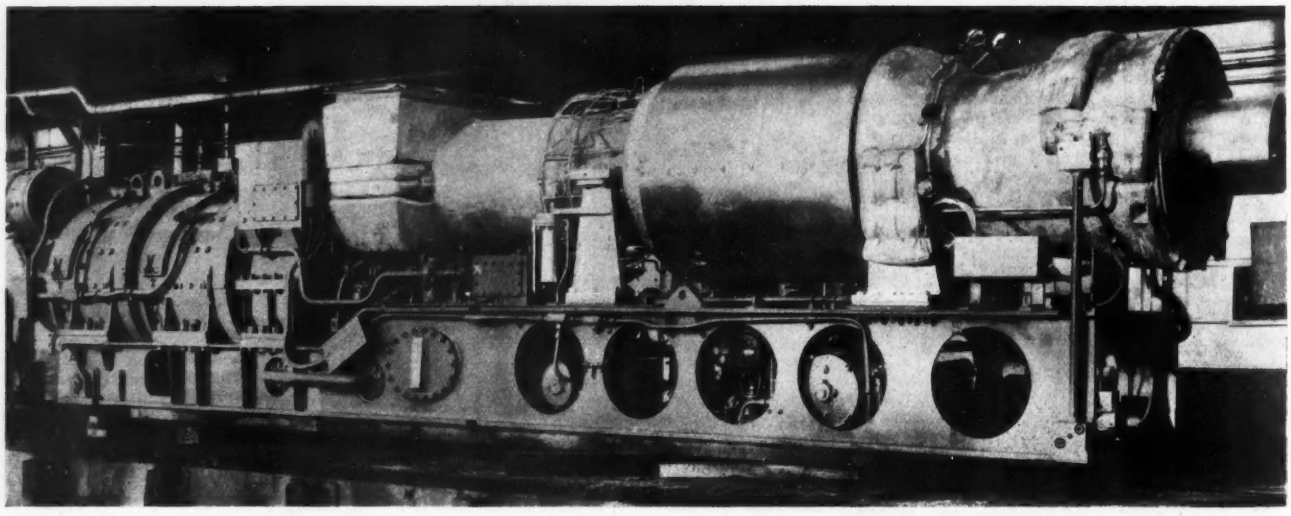
There are two 2000 h.p. gas turbine power plants, one of which is illustrated herewith. Each plant consists of two generators, a reduction gear, a twenty-three-stage axial-flow compressor, twelve combustors and the turbine and auxiliaries mounted on a common bed-plate which is supported on three points on the locomotive.

The original turbine rotors were made of single solid forgings with the blading installed in axial grooves. Operation of this rotor design in stationary service showed that this construction developed thermal cracking at the blade root slots when subjected to rapid temperature changes. As a result of this stationary operating experience, disc rotors were made to replace the solid rotors originally installed. Experience to date indicates that the disc rotors will eliminate this difficulty.

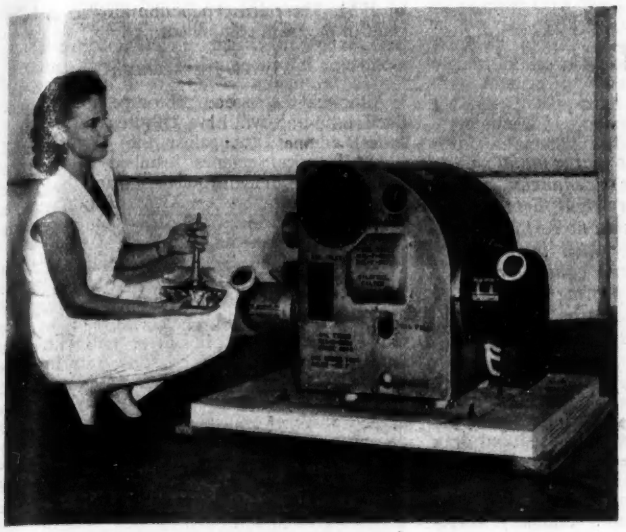
A failure of the right-hand gas turbine blading occurred after the first 175 hours of road operation. The cause of this failure was traced to an unusual tunnel operation some weeks previously when the unit was subjected to a 1750 deg. Fah. inlet temperature. It is of interest to note that the unit was operated for six and a half hours after the blade failure occurred. Inspection was finally made because the unit was reported to be low on output power. Modifications to the turbine control system and normal tunnel operation have prevented further difficulty of this kind.

After operation with various residual oils at standstill tests at the East Pittsburgh Works of the company, and in operational tests on the Pittsburgh and Lake Erie Railroad in March, 1951, a detailed examination was made of the turbines. This examination showed that small hairline thermal cracks had started in the lock slots of the original solid rotors, thus confirming the experience found in stationary service with the same design of rotors. Before the unit was subsequently placed in service on the Pennsylvania Railroad in February, 1952, the solid rotors were replaced by disc rotors. After operation on the Pennsylvania and the Missouri-Kansas-Texas Railroads, during the past year, the gas turbines were again removed for complete inspection. This inspection showed that the gas turbines were in good condition, with the exception of some minor thermal cracks in the base of the root grooves. A slight machining modification was made to the turbine discs and additional cooling air provided to the turbine rotor face before the locomotive was delivered to the Chicago and North-Western Railroad in September, 1952, for further test operation.

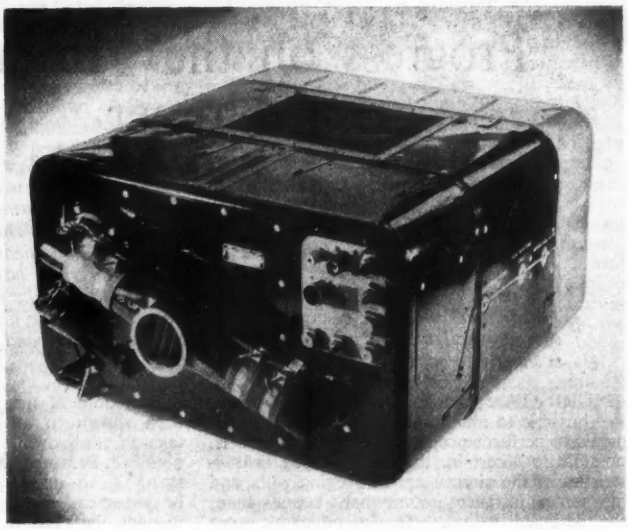
Locomotive power is controlled by varying the turbine speed and the generator excitation. A pneumatic valve operated by a cam on the controller speed handle sets the control pressure



2000 h.p. Power Plant of Westinghouse-Baldwin 4000 h.p. Gas Turbine Electric Locomotive



Solar Aircraft 45 h.p. Gas Turbine Electric Generating Set



Air Research 65 h.p. Gas Turbine Compressor Packaged Unit

of the turbine governors which, in turn, set the fuel pressure. The generator excitation also is set by the same control pressure in proportion to throttle handle movement. An over-riding system based on the pressure developed by the turbine compressor and the turbine exhaust temperature prevents over-excitation during speed changes and under high-temperature conditions. This system of stepless control has proved satisfactory. The two traction motors on each bogie are electrically separated and supplied by one of the four generators. They are operated in series at speeds below 50 m.p.h. and in parallel at higher speeds. Field shunting of the motors occurs automatically in both connections to allow the full utilisation of the turbine power up to the locomotive maximum speed of 100 m.p.h. The transition from series to parallel and vice versa is automatic.

A waste heat boiler for fuel and train heating and a supplementary standard oil-fired steam generator for additional steam, as required, are fitted. The rated capacity of the waste heat boiler is 2000 lb per hour at the full rating of the turbine.

Further test operations were conducted in 1952 on the Allis-Chalmers 3750 h.p. coal-burning gas turbine locomotive power plant, which has been erected within locomotive cab contour limitations at Dunkirk, New York, by the Locomotive Development Committee of Bituminous Coal Research, Incorporated. The stationary test installation of this unit was described and illustrated in our issue of November 14, 1952. A first 750-hour high-temperature, high-load test has now been completed, with the burning of more than 2,000,000 lb of high volatility bituminous coal and the generation of more than 2,000,000 h.p.-hr. The average thermal efficiency of the plant during this test period was above 18 per cent and the average load on the unit was approximately 2800 h.p., equivalent to about 75 per cent of its rated capacity. The maximum load carried so far has been 4250 h.p. If the series of tests of this stationary plant at Dunkirk continue to prove successful, the power plant will be installed in a two-unit locomotive chassis. Extensive tests will then be run to determine the suitability of this form of motive power under actual railway service.

Auxiliary Gas Turbine Plants

Development work continued during the past year on the "Mars" and "Jupiter" gas turbine engines of the Solar Aircraft Company, of San Diego, California. Detailed descriptions of these units were published, respectively, in The Engineer of January 25, 1952, page 147, and March 28, 1952, page 428. Recently, the firm obtained its first large production order for the simple and compact 45 h.p. "Mars" gas turbine, illustrated herewith, which will be used to drive auxiliary and emergency power generating sets in the Douglas "C–124" "Globemaster" cargo and troop transport aircraft, which is being produced for the U.S. Air Force. Exact details of the contract were withheld by military security, but it may be reported that "more than 100" of the units will be built. Production deliveries will start this year. In use on the cargo aircraft, a push button starts the generator set in a matter of seconds, using batteries for starting power. The turbine will operate on the same high octane fuel used for the four "Wasp Major" piston engines powering the "C–124," although it has been established that the turbine also can run on diesel oil and natural gas. The generator sets are designed for use either when the aircraft is on the ground or when it is in flight.

The model "T–400" "Jupiter" engine is substantially larger than the "Mars" engine. In its initial application as the prime mover for an electric generator set, to provide electric power on shipboard, the unit operates a 250kW emergency generator. The basic engine, controls and reduction gearbox together weigh only 561 lb, which is remarkable in view of the fact that it has been designed for a much longer life than contemporary aircraft gas turbines. The unit is 5ft long, and both its height and width are less than 3ft. It has now been installed on a naval vessel replacing a diesel engine-driven generator set of about ten times its size and weight. The company is now developing a similar gas turbine engine to have a variable speed output in the 500 h.p. range, which is intended to be used by the U.S. Navy for the propulsion of small craft.

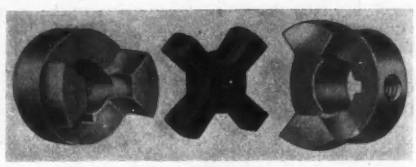
A detailed description of the compact and portable 175 h.p. gas turbine engine, which was developed by the Boeing Airplane Company, of Seattle, Washington, in conjunction with the Bureau of Ships, U.S. Navy, was published in The Engineer of January 19, 1951. The engine is now being manufactured on a production basis for the U.S. Navy, and is being employed as a prime mover driving power generating sets on minesweepers. During the past year the gas turbine was also installed experimentally in a "K–225" helicopter of the Kaman Aircraft Corporation.

A very compact gas turbine-driven air compressor is now being produced by the AiResearch Manufacturing Company, of Los Angeles, California. The model "GTC 43/44" illustrated weighs only 88 lb and has a rating of 65 air h.p. It is a single-shaft bleed-off machine mainly used to supply compressed air for aircraft auxiliary power systems. The turbine has a speed of 40,000 r.p.m., a compressor flow rate of 1·9 lb per second, and a pressure ratio of 3 : 1. The maximum gas temperature ranges between 1500 deg. and 1600 deg. Fah. The compressor has two centrifugal stages with impellers of backward-curved design. The maximum bleed is about 35 per cent of the total compressor flow. The air may be bled directly after the compressor or after the combustor if hot gas is required, or air may be bled from both points and mixed to give an intermediate temperature. Two "can type" combustors are utilised and their output is fed into a single-stage, 90 deg., inward-flow, radial turbine having a twelve-blade rotor made of "Inconel X."

A Small Flexible Coupling

A recent addition to the range of flexible bearings, couplings and mountings made by Howard Clayton Wright, Ltd., Wellesbourne, Warwickshire, is the "Torflex" type "K" coupling. This coupling, as can be seen from the accompanying illustration, which shows the three principal units, is of particularly simple construction.

The two metal end elements of the coupling are bored and keywayed to shaft dimensions



Small Flexible Couplings

and the lugs projecting from their inner faces are designed to mate with those of the spider-shaped flexible inner element through which the drive is transmitted. The couplings are particularly intended for "in-line" working up to specified torques, although the flexible inner elements permit a certain amount of latitude in assembly.

The couplings are at present made in four sizes for shafts of ¼in, ⅜in, 1in and 1¼in diameter for transmitting, at 1000 r.p.m., maximum horsepowers of ½, 1, 2¼ and 5¼ respectively.

Literature on Industrial Diamonds.—Since it was established in 1943 the Industrial Diamond Information Bureau, 32–34, Holborn Viaduct, London, E.C.1, has collected a large number of publications on diamond occurrence and mining, diamond tools, diamond polishing, gemstones, crystallography, and related mechanical, physical and technological sciences. It was felt that this library could be more usefully employed internally, as well as externally, if a classified list of these publications were available. This has now been done in a list which is classified according to the universal decimal classification. It is intended to publish annual supplements to the list towards the end of each succeeding year. We are informed that publications contained in this list could be made generally available on loan for a period of fourteen days in England. A limited number of copies of the list is being made available for free distribution, and applications should be made to the Bureau.

Progress on the "Britannia" Airliner

We have received from the Bristol Aeroplane Company, Ltd., a report of the initial phase of the flight test programme which has been proceeding with the "Britannia" airliner. This aircraft first flew in August last year, and during forty-eight flights a total of forty-six and a half hours has been logged. It is stated that no serious trouble has been encountered and that no major modifications which might have delayed the progress of the production aircraft, have been called for as a result of these trials. The company is confident that the basic proving of the "Britannia" has thus been done. Resonance tests on the first prototype in the assembly hall at Filton have also been concluded and the second flight-testing phase is shortly to commence.

DURING the first exploratory flying, it was possible to make only preliminary measurements of performance, but, so far as it has been possible to ascertain, the lift and drag characteristics of the aircraft are in keeping with, and in some instances somewhat better than, the designed values. The aerodynamic-servo flying control system has proved to be most effective. Elevator response was, in fact, found to be a little too good, and so the horn balance area was reduced and one of the tabs changed from servo to trimming duties. Lateral control is positive, and more than adequate right down through the stall, while directional control and rudder response are precise. The great advantage of the "Britannia" flying control system is that by "flying on the tabs" all the benefits of a powered control system are obtained; yet the weight of the system is actually lighter than that of a conventional direct-control installation. The degree of artificial "feel" is adjustable.

The aircraft has so far been flown at various gross weights up to a take-off weight of 125,000 lb (the all-up weight of the prototype is 130,000 lb) and at centre of gravity positions varying between 12 and 35 per cent standard mean chord. The aft limit of 35 per cent is appreciably beyond that which will ordinarily be used, and it is noted in the report that the aircraft remained tractable at this extreme condition. The aircraft has been landed at 120,000 lb, although the normal landing limitation for the prototype is 105,000 lb.

The "Proteus 2" turbo-prop engines have behaved admirably throughout the flight trials. The power response is particularly marked owing to the acceleration characteristics of these engines, and this is made abundantly clear by the shortness of take-off run and the rapid initial climb. Having a free power turbine the freedom of the propellers to windmill has been shown to advantage during asymmetric take-off trials owing to the vastly reduced drag obtained. Because the degree of asymmetric power swing is so much less than would otherwise be expected, the pilot can regard with less urgency the need to feather. Similarly, three-engine landings have been made, and here, too, the characteristics of the aircraft have been proved to be straightforward and viceless. A great many relights have been made during flight at various altitudes and the easy ability of the "Proteus" in this regard, first established in the "Lincoln" flying test bed at altitudes up to 30,000ft, has been satisfactorily confirmed.

The drag of the double-slotted flaps at their full 50 deg. deflection is considerable, and if necessary a very steep glide path may be used. Power-off stalls over a wide range of conditions have been explored. Stall warning is definite and sufficiently early, and the stall itself is quite gentle. The aircraft shows no tendency to drop one wing more readily than the other and frequently stalls level.

The Second Prototype.—Work on the second prototype aircraft is well advanced and is up to schedule. The aircraft will be powered with "Proteus 3" engines, and it is expected that the maiden flight will be made during the summer. The second prototype will be completed to the normal production aircraft standard, with tankage increased to 6800 Imperial gallons and gross weight advanced to 140,000 lb.

Production Aircraft.—The first of the production aircraft is now in process of final assembly, and the fuselage of the second production aircraft is out of the main component jigs and ready for delivery to the assembly hall. Both of these aircraft are scheduled to fly during the early part of 1954. The third production aircraft is being built in the main component jigs.

Power Installation

Although the second prototype and the production aircraft will have "Proteus 3" ("705" series) engines as against the "Proteus 2" ("625" series) engines installed in the first prototype, the fundamental design and the greater part of the component design of both variants are common. More than 13,000 hours' running has to date been amassed by the "Proteus," including 940 hours' flight experience gained in the Lincoln test bed before the "Britannia" flew.

It is stated that engine handling and response have been consistently excellent, and jet pipe temperatures have proved to be well within the limits under all flight conditions. Starting has been good at all times, being both rapid and positive. The throttle-control system has been amply proven, and the temperature-override device in particular has demonstrated its very real value in preventing excessive jet pipe temperatures, especially while manœuvring on the ground with engines operating in the range between ground and flight idling.

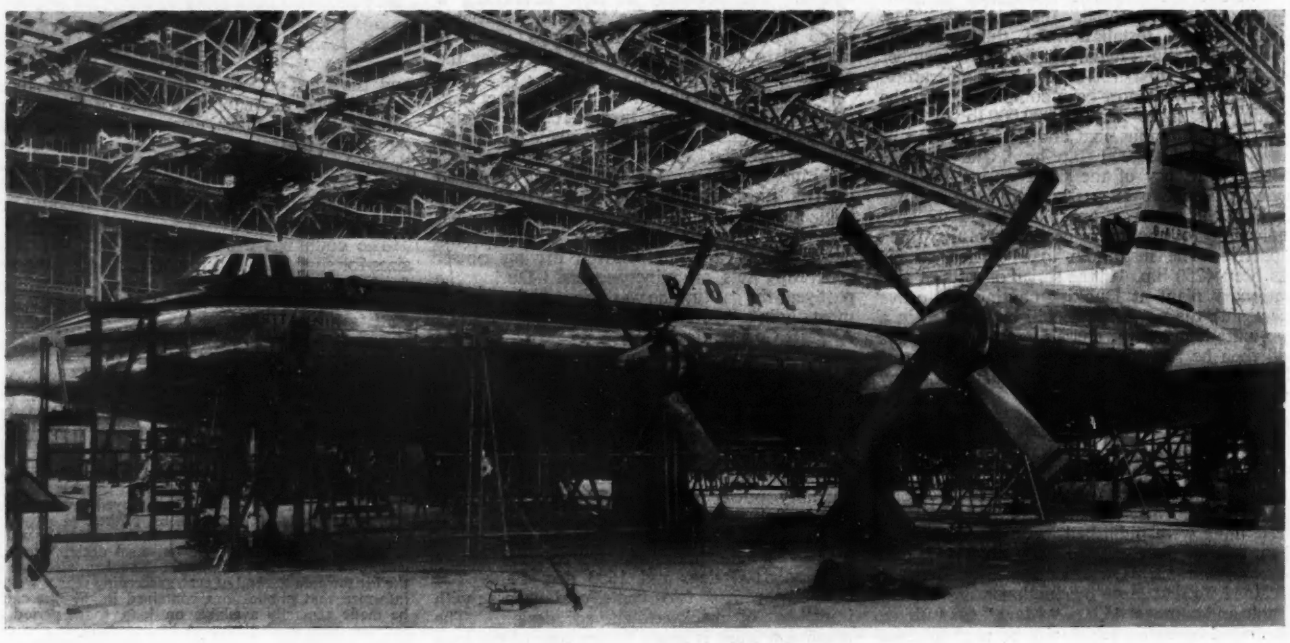
To check the effectiveness of the jet pipe and shroud fuel drainage systems, "wet" starts of particular severity have been carried out in flight. The initial discovery of a slight leakage resulted in modification to the shroud, and further tests have demonstrated that the leakage has successfully been overcome.

As a result of the bench and flight trials carried out with the "Proteus," a few design modifications have been found desirable. A refinement to the compressor-rotor thrust bearing gives improved bearing cooling; detail improvements to the reduction gear are designed to give extended life at the higher powers now being extracted from the engine; first and twelfth-stage compressor-rotor blades have been revised to obtain increased fatigue life, and the compressor blow-off valves and operating system are being modified to give complete reliability.

The "Proteus 3" will incorporate a bleed from the turbine for the cowl and wing anti-icing systems, compressor entry guide vanes of hollow section with a hot air feed for de-icing, and a tapping from the compressor for cabin pressurisation supply.

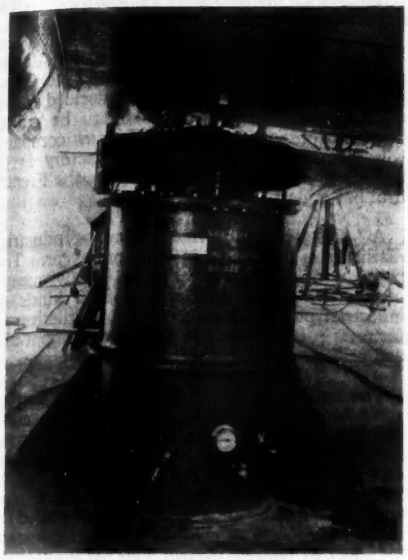
Four "Proteus 705" engines have been built to date and accepted by the Ministry of Supply.

Since the first test, all running—including two consecutive runs to the conditions of a twenty-five hours' special category test—has been at the design rating of 3350 s.h.p. for take-off. Performance has been maintained, a representative



The "Britannia" Mounted for Resonance Tests

test showing an output of 3360 s.h.p. after an accumulated running time of some 200 hours on the particular engine concerned. The residual jet thrust was 1190 lb, giving a total equivalent horsepower of 3830. Oil consumption has not exceeded 1 pint per hour and the cleanliness of the engine and absence of oil vapour from the breathers were particularly noteworthy. A set of



Low Frequency Main Support for Resonance Tests

combustion chambers which had been used for 270 hours' running required only burner rectification to render them satisfactory for further service.

Our first illustration shows the prototype aircraft undergoing resonance tests. The aircraft is supported by a low-frequency nose sling (suspended from one of the overhead cranes and incorporating a cam-operated spring) and on two low-frequency supports designed by the company. The exciter motors are below the nose wheel bay. Frequencies recorded at various pick-up points on the aircraft structure were transmitted to a control van manned by a team of observers.

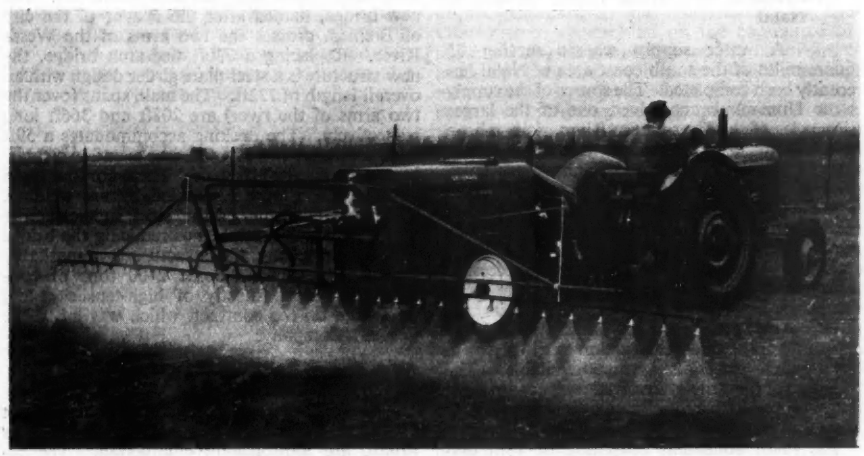
One of the two low-frequency supports supporting the "Britannia" at the main jacking points during these tests is illustrated. The support, of simple design, consists of a large volume tank which provides an extremely low degree of damping, the frequency of the mass mounted on the tank being dependent on a very small change in volume. The tyre on top of the support, filled with nitrogen, provides a flexible mounting for the aircraft. "Sky-hi" jacks are built into the tank for normal ground handling of the aeroplane, but are inoperative while tests are in progress.

Crop Spraying Equipment

THE progress of scientific farming in the last ten years or so has included notable developments in methods of weed and pest control. Increased yields of various agricultural crops have undoubtedly been effected by the careful application of suitable chemicals for eradicating or reducing to a minimum weeds and pests against which the farming industry has had to battle for centuries. In recent years many insecticides and weedkillers have been produced for application by spraying on grass, cereal and root crops or on the soil itself. The development of these chemicals has naturally influenced the design of the equipment required for applying them to the area to be treated, and the production of spraying machinery has consequently taken an important place in the agricultural engineering industry. The function of a modern spraying machine has been described as follows. To deposit a certain number of milligrammes of a chemical per square inch of plant, insect or soil; or to establish a cloud of solid or liquid chemical in the vicinity of the crop to be treated; or to establish a certain gas concentration in the vicinity of the insect to be controlled.

In January, 1949, a paper was presented by Dr. W. E. Ripper to the Institution of British Agricultural Engineers, which outlined developments in agricultural spraying and described the various kinds of machine employed for the job. In that paper reference was made not only to tractor-drawn and tractor-mounted sprayers, but also to the use of helicopters and other aircraft for crop spraying operations. Dr. Ripper is the managing director of Pest Control, Ltd., a company which was established at Harston, Cambridge, early in 1939 to carry out spraying work by contract. By the end of the war the influence of chemical development on the design of spraying machinery was very pronounced, and, in addition to its chemical works at Harston, Pest Control, Ltd., set up an engineering works at Bourn, a few miles away, for the manufacture of liquid sprayers. While the firm continues its contracting business, both in this country and overseas, more and more farmers and fruit growers are finding it necessary to include a sprayer in their equipment.

Last week we were invited to spend a day at the engineering works at Bourn, Cambridge, of Pest Control, Ltd., to watch demonstrations of the machines which the firm makes for its contract work and for sale. These machines range from a tractor-mounted low-volume sprayer, with a tank capacity of 45 gallons, to a trailer sprayer with a 500-gallon tank, and fitted with a three-cylinder reciprocating pump capable of giving pressures up to 800 lb per square inch. Among the medium-pressure sprayers produced by the firm is the "Fieldmaster," a 100-gallon trailer machine which was shown for the first time at last year's Smithfield Show, and was described in our issue of December 19, 1952.



200 Gallon Crop Sprayer

The steel tank is of all-welded construction and is treated internally against corrosion. The effective spraying width of the "Fieldmaster" is 24ft.

Another of the firm's recent productions—described as an "all-round sprayer for the medium-sized farm"—is the "Universal Major," shown in the accompanying illustration. This machine has been designed for applying both solutions and suspensions at high or low volume and at medium or low pressure from 5 to 100 gallons of spray per acre. Its all-welded steel tank, of 200 gallons capacity, is treated internally against corrosion. The pump, known as the "Arun," is another new product of Pest Control, Ltd. It is a positive displacement pump, with twin cylinders horizontally opposed, which is driven from the tractor power take-off shaft. At a power take-off speed of 500 r.p.m. the pump gives an output of 15 gallons a minute at 200 lb per square inch. All the parts of the pump coming into contact with spray chemicals are resistant to corrosion and the cylinders are lined with vitreous enamel. The tank of the "Universal Major" is provided with a mechanical agitator which is driven from the main pump shaft. Two sets of paddles are fitted to the agitator shaft, and the shaft itself is mounted in adjustable, leak-proof glands. Filtration of the liquid takes place at three stages throughout the machine by means of a tank filter basket, a filter on the intake side of the pump, and by a filter provided in each spray nozzle. The spray bar assembly consists of a 25ft bar in three sections, fitted with thirty-three nozzles, and for transport the outer sections of the spray bar can be folded alongside the machine. The equipment also includes a 2ft 6in hand lance fitted with three nozzles, and a trigger valve, and attached to 60ft of high-pressure hose. The machine is mounted on a cast steel axle, in two sections, the two wheels being fitted with 8·00 by 20 rubber tyres.

During the demonstration last week, emphasis was given to the safety devices which the firm has developed in order to give adequate protection when dealing with toxic chemicals. Damage can be done, of course, by the drift of weedkillers on to neighbouring susceptible crops, and to counteract this, Pest Control, Ltd., has devised the "Nodrif" boom, which it fits to its contract machines. These machines normally have a spray bar 40ft wide, in three sections. The two outside sections are supported by castor wheels which keep the spray bar a constant distance from the ground, and in the "Nodrif" arrangement each of the three sections is equipped with an individual wind shield so disposed that the wind is deflected over the shield. To guard against side winds folding triangular deflectors are provided and a serrated rubber curtain along the lower edges of the deflectors helps further in preventing wind from getting underneath the shield. Other safety measures include a gas-proof, air-conditioned tractor cab, and effective protective clothing for the operators. These safety measures were described in some detail in our issue of April 13, 1951.

In connection with its contract services, Pest Control, Ltd., has established a number of depots in this country and abroad. At each of them there is a biological laboratory for the examination of plant material, storage facilities for chemicals, workshops and landing space for helicopters. The company also maintains at its headquarters a sizeable biological and chemical research department for the investigation of new insecticides, fungicides and weedkillers. The research service is available to Governments, plantation organisations and growers for the investigation of particular problems related to insect and weed control.

LIGHT ALLOY MARINE EQUIPMENT.—We have received an illustrated brochure from Non-Corrosive Metal Products of Yiewsley, Middlesex, which deals with light alloy ships' equipment, including such items as gangways, accommodation ladders, life rafts, hatch covers and other small fittings.

African Engineering News

(By Our South African Correspondent)

South Africa as a Producer of Uranium

South Africa appears to be now well on the way to becoming a supplier of an important share of the world's needs of uranium. How important this ancillary product of the gold mines is to South Africa can be gauged from the fact that, under the present programme by which a score of mines are being equipped for production, the capital cost will be more than £40,000,000. It is estimated that the gross annual revenue from uranium, when all these producers are in operation, will be not less than £30,000,000. That the West Rand Consolidated Mine should be the pioneer producer of this material is not merely fortuitous, for ever since the presence of uranium in the reefs of the Rand was detected thirty years ago, the importance of the upper reefs of the West Rand as a source has been recognised. It was as far back as 1923 that the presence of "uranite" in the gold concentrates was discussed, but no likelihood was then foreseen of the mineral being of any commercial importance.

In the recovery of uranium from the slimes after the gold has been extracted, large quantities of sulphuric acid are used and, by a providential circumstance, the radium-rich reefs also carry a considerable proportion of pyrites. For years West Rand Consolidated has been disposing of iron pyrites to the explosives industry, but now the pyrites will be treated for sulphuric acid on the spot. A large sulphuric acid plant has been brought into operation alongside the uranium production plant. Randfontein Estates' uranium plant is also to have its sister sulphuric acid-producing equipment and also certain other of the mines that are to be uranium producers.

Completion of a Water Supply Scheme in Natal

A water supply scheme serving 35 square miles of the south coast area of Natal has recently been completed. The source of the supply is the Umzimkulwana River, one of the larger tributaries of the Umzimkulu River, rising above Harding. The dam, which is just above Hell's Gate at an elevation of 1862ft above sea level, provides a reservoir of 420 m.g. capacity. All pipe-laying has been done departmentally, while the building of the purification works, service reservoirs and the dam were carried out by contract. To lay the 18in main it was necessary to construct some 5 miles of road in the Oribi Gorge in formidable terrain. Contracts for pipes, plant and other materials were placed early in 1948, while construction work began in 1949, when materials became available. The number of contracts involved was twenty-six, and their range and character was extremely wide.

The main aqueduct, consisting of 18in diameter steel pipe, derives its supply from an intake weir in the Oribi Gorge, about 10 miles downstream of the dam, and follows a rugged and circuitous route of 11 miles down the southern side of Oribi Gorge until it reaches the purification works, which are close to the main road from Port Shepstone to Harding and about 4 miles from Port Shepstone. At the purification works the main trunk supply bifurcates to the northern and southern sections of the scheme in pipes of 10in and 12in diameter, respectively. The extent of the main pipelines included in the scheme, ranging in size from 18in to 2in diameter, is nearly 200 miles. The purification works are 497ft above sea level. They include sedimentation basins, where the grosser impurities are removed by chemical precipitation, rapid gravity sand filters, where the water is finally clarified, and chlorination and ammoniation machines for final sterilisation. From these works the water passes into a 1 m.g. reservoir.

The ascertained capacity of the 18in main aqueduct is virtually 3 m.g.d. With a capacity of 1·25 m.g.d., the purification works will have no difficulty in meeting the present demand of 600,000 gallons and will provide an ample margin for supply. In addition, they are capable of being extended easily at small cost. The entire area is served by gravitation except for a terminal section at the extreme southern end of the system and a few isolated high spots within the region of supply, where subsidiary pumping arrangements have been necessary. A balanced service to the entire area is maintained by eighteen service reservoirs of varying capacity, their combined capacity being about 2·5 m.g. The plans provide for the construction of additional reservoirs when required. The opinion has been expressed that this scheme has cleared the way for the early "urbanisation" of the whole south coast.

Bailey Bridges in Belgian Congo

In October, 1952, a Bailey bridge was launched across the Ituri River on Mambasa-Beni highway in the Eastern Province, Belgian Congo. The bridge, which is the thirty-fourth structure of this kind erected in this province, constitutes a part of important public works carried out for the construction of the Mungbere-Mambasa-Beni feeder line. On the Mungbere-Mambasa section four Bailey bridges erected in 1950 have replaced three ferry boats crossings. The new bridge, over the Ituri at Teturi, is 275ft long, consisting of three spans with a central span of 152ft. The structure rests on piers and abutments 23ft high. The new Ituri bridge weighs about 100 tons.

Continental Engineering News

(By Our Continental Correspondent)

The Mayor Smidt Bridge, Bremen, Germany

Another new structure was added recently to the numerous German bridges which have been rebuilt since the end of the war. The new bridge, named after the Mayor of the city of Bremen, crosses the two arms of the Weser River. Replacing a 730ft tied-arch bridge, the new structure is a steel plate girder design with an overall length of 732ft. The main spans (over the two arms of the river) are 208ft and 366ft long respectively. The decking accommodates a 59ft wide roadway, two 5ft cycle tracks and two cantilevered footpaths 11ft wide. There are four main girders, which were assembled by arc welding. The main elements of the steel superstructure are of high-tensile steel, thus reducing the bridge weight and giving the structure a remarkably slender appearance. Some 2400 tons of constructional steel (mostly of high-tensile grade) were used on the contract, which was let to the G.H.H. Company.

An Oil Refinery in Italy

Works for the erection of an important oil refinery, "Condor," situated at Rho, near Milan, are approaching completion. The refinery, whose capacity will be 1,300,000 tons annually, will be able to supply Italy and various countries of Central Europe with all kinds of oil products. It will be equipped with a distillation plant operated at atmospheric pressure with a daily capacity of 30,000 barrels, and there will also be a catalytic cracking plant with a daily output of 15,000 barrels, various recovery installations and other ancillary units. The new refinery will be connected with the city of Genoa by a pipeline, some 70 miles long, having a diameter of 12in. A storage station at present is being built at Fegino, near Genoa.

A Canal in the Port of Ghent, Belgium

A ring canal is now being built in the Ghent area. This canal connects the Terneuzen canal, the Ghent-Bruges canal, the Lys River and Scheldt (Escaut), thus establishing a convenient link between the port of Ghent, Northern France and the Borinage colliery area, and permitting the drainage of flood water from the Lys and Scheldt. During the past year the cutting of this canal proceeded between the Upper Scheldt and the Lys. The dredged material was used as fill for the new Brussels-Ostend motorway.

French Engineering News

(By Our French Correspondent)

The famous coking plant at Carling has been equipped with two new batteries of twenty furnaces each, which will increase the production of coke to 1200 tons daily, whilst gas production will increase to 600,000 cubic metres.

When by the end of 1953 the Carling plant is completed it will have some 160 ovens producing one-tenth of entire French production.

* * *

It is learned in Paris that the Glaces et Verres of the North of France and the Monsanto Company of St. Louis, Missouri, have decided to set up a Franco-American company to be called Société Monsanto-Boussois. The new company will manufacture plastics, and a factory is to be built at Wingles, near Lens, where the French firm has a glass works.

* * *

A Congress of International Industrial Æsthetics is to be held in Paris next year. The purpose of the Congress is to study means of improving the appearance of all kinds of industrial plant and machines; ventilation in factories; the best colours for workshop walls and ceilings, and general factory atmosphere.

* * *

The outlines and basis for the second Equipment Modernisation Plan have now been completed. The purpose of the plan is to bring France into line with other countries. It is estimated that, while the first plan increased French production based on 1946 at a rate equal to that of other countries, it failed to increase production based on 1938 to the same level as that reached abroad, and for that reason the new plan has been drawn up.

The industrial production target is 30 per cent above the present level and is to be reached by 1957. Fuel production in all forms is to increase by 25 per cent, and agricultural production by 20 per cent. The figures put forward in the plan are as follows:—coal, 60,000,000 tons in 1956–57, 65,000,000 tons by 1960; electricity, 50 milliard kWh in 1956–57, 65–70 milliard kWh in 1960; oil refining, 25,000,000 tons in 1956, and steel, 15,000,000 to 16,000,000 tons in 1956.

The plan will not only take into account the basic and heavy industries, but will also include smaller industrial units. Aid will be granted to all small firms ready and willing to modernise their plant. Aid will be given only to firms producing such goods and products failing to meet competition on the world market.

In those parts of the country where specialised labour is incapable of doing other work, the Government plans to introduce new industries and to encourage labour to learn other trades.

* * *

It is stated that French electricity production in 1952 was about 40,200 million kWh as compared with 38,279 kWh in 1951 and 18,864 million in 1938. The increase was due in the main to the development of hydro-electric resources. It is pointed out that these figures do not include the recently completed schemes at Tignes and Donzere-Mondragon. Production is therefore considered satisfactory, although it is pointed out that with the constant increase in consumption the development of new sources of energy production is absolutely essential.

* * *

Provisional figures for French coal production during the past year are stated to be 57,353,000 tons, against 54,975,000 tons in 1951 and 52,539,000 tons in 1950. It is pointed out that the increase in production by 2,378,000 tons in a year is of particular interest as the number of miners employed continued to decrease. In 1952 some 167,549 miners were at work at the coal face against 171,487 in 1951. In 1930, when the last production record was reached, France had 209,000 miners working at the coal face. The increase in production per miner last year reached 1361 kilos, against 1307 in 1951 and 1201 in 1950. This year further development is expected following the laying down of a special programme. The provisional estimate given is 58·5 million tons with an increase per coal face miner to 1425 kilos per day. These figures, of course, depend upon the rate of modernisation in the mines.

Industrial and Labour Notes

Coal Production

The saleable output of deep-mined coal in Great Britain last week amounted to 4,430,500 tons and of opencast coal 230,900 tons, giving a total for the week of 4,661,400 tons. That total was 16,000 tons above the preceding week's output and more than 200,000 tons above the output in the corresponding week of last year. In the first four weeks of this year, coal production amounted to 18,513,100 tons, compared with 18,190,400 tons in the corresponding period of 1952.

The Minister of Fuel and Power, Mr. Geoffrey Lloyd, was questioned in the House of Commons last Monday about deep-mined production. In reply, he said that last year's deep-mined output, estimated at 214,350,000 tons, showed an increase of 1·2 per cent over 1951. As, however, last year was a leap year, the extra day's production accounted for about 800,000 tons of the total. The Minister added that improvement was needed if the Ridley committee's estimates of deep-mined coal output were to be met.

Wages and Hours in 1952

According to statistics published by the Ministry of Labour, there was an increase in the average level of weekly rates of wages last year of about 6 per cent, compared with about 11 per cent during 1951 and 4 per cent in 1950. The current index of weekly wage rates (June 1947=100) was 134 for all workers at the end of December last, compared with 126 a year earlier. It is estimated that nearly 11,500,000 workpeople received wage increases amounting at the end of last year to approximately £4,500,000 a week. The Ministry says that, during the whole period for which information is available, the amount of increase and the numbers affected have been exceeded only in 1951.

Last year's increases in wage rates affected 2,942,000 people employed in the industry groups classified as "engineering, shipbuilding and electrical goods," "vehicles" and "metal goods not elsewhere specified." The estimated net weekly increase in those three groups is given as £1,157,100. Among the principal changes in wage rates last year, the Ministry mentions those which became effective in the engineering and shipbuilding industries. In the engineering and allied industries, the minimum time rates for female workers of eighteen and over were increased in January, 1952, by 10s. 1d. a week, with a corresponding increase for payment-by-result workers and proportional increases for younger workers. In April, there were increases varying from 5s. 6d. to 11s. a week, according to age, for apprentices, youths and boys. In November, male time-workers and payment-by-result workers of twenty-one and over received an increase of 7s. 4d. a week or twopence an hour, female workers of eighteen and over received 6s. 5d. a week or 1¾d. an hour, and there were proportional increases for younger male and female workers. In the shipbuilding and ship repairing industry apprentices, youths, boys and girls, received increases in May varying from 6s. to 11s. a week. In November, there was an increase of 7s. 6d. a week for all adult male time-workers and payment-by-result workers, with proportional increases for women and juvenile workers.

During last year, the Ministry of Labour says, very few changes in normal weekly hours of labour were reported. About 2500 workpeople had their normal hours increased by 1¼ hours a week, and for about 56,000 workpeople there was an average reduction in normal working hours of about 3 hours a week.

Industrial Disputes

Stoppages of work through industrial disputes in the United Kingdom last year caused a loss of 1,793,000 working days. The Ministry of Labour has stated that about 1·5 per cent of the workpeople in civil employment were involved in these stoppages, the loss of time for each worker involved averaging about five working days during the year. In last year's stoppages, which numbered 1718, there were about 416,000 workpeople involved directly and indirectly. In 1951, there were 1719 stoppages of work through disputes, involving 379,000 workpeople and resulting in the loss of 1,694,000 working days.

Last year, the coal mining industry accounted for about one-third of the time lost on account of stoppages. Altogether, in the coal mining industry, 1225 stoppages through disputes were reported to the Ministry. In the engineering industry there were 62 stoppages, involving 23,900 workers and causing a loss of 185,000 working days; there were 62 stoppages in the shipbuilding industry, involving 13,500 people and resulting in a loss of 87,500 working days, while from the vehicle building industry there were 47 stoppages reported, involving 38,900 workers and causing a loss of 469,000 working days.

Time Rates of Wages and Hours of Labour

The seventh annual edition of the book entitled *Time Rates of Wages and Hours of Labour* has just been published (at 6s. 6d.) by H.M. Stationery Office. The book is compiled by the Ministry of Labour, and in the main tables there are shown, for the principal industries and occupations in the United Kingdom, the minimum or standard time rates of wages as fixed by voluntary agreements, or by joint industrial councils, or by Statutory Orders under the various Wages Councils Acts.

Particulars are also given of the normal working hours, and, where available, of the basic rates for pieceworkers and the additional rates payable to shift workers and night workers and the arrangements, where they exist, for a guaranteed weekly wage. In addition, the volume contains, in appendices, the rates of wages for young people in a selection of industries, and overtime rates and the arrangements for paid holidays in the principal industries. It should be noted that all the details given in the book relate to the position as at October 1, 1952.

Capital Replacement Costs

In response to inquiries for assistance on these problems, *The Economist* Intelligence Unit states that it now compiles index numbers showing changes in the cost of replacing buildings and plant of different kinds, e.g. machine tools, electrical installations and commercial vehicles. These index numbers refer only to home prices of plant and machinery produced in this country. The prices used in compiling the indices are obtained from over 150 manufacturers whose co-operation is making this service possible.

It is interesting to note that the curve of average prices, covering some 200 separate items, began to level off last year. After rising at an accelerated pace throughout 1951, the index increased by no less than 6 per cent in the first three months of 1952. This, it is suggested, probably constitutes a post-war record. A sudden lull followed which lasted through the rest of the year. In the nine months from March to December, 1952, the average cost of new buildings, plant and equipment rose by less than 2 per cent as compared with a 12 per cent rise during the same period in 1951. The behaviour of capital goods prices last year corresponds to a period in which supply tended to come abreast of demand on the home market. The ending of the initial allowances last April coincided with a recession in some consumer trades. Moreover, during 1952, the machine tool industry was coming to the end of its defence orders. Last year was also a period of relative stability in wage and material costs. In view of the more competitive conditions ahead, it became the policy of some makers of capital equipment to freeze their prices at the levels ruling about the middle of the year.

It remains to be seen, *The Economist* Intelligence Unit says, whether this policy will be adhered to in the near future. Some plant and machinery manufacturers raised their prices in the course of the last quarter of 1952, but many others appear to have absorbed the wage increase granted to engineering workers last November without raising their prices. Sharper competition in export markets this year may well reduce the scope for price reductions in the home market.

The European Steel Industry

The steel committee of the United Nations Economic Commission for Europe has recently concluded a meeting at Geneva, at which it surveyed the present situation of the European steel industry and gave particular consideration to some of its medium-term and long-term problems. A report of the proceedings, which has been circulated this week, says that the main interest of the committee was centred upon two major problems. The first of those problems arises from the striking growth in Europe of capacity to produce flat steel products, and the need, on the one hand, to maintain and develop consumption if that capacity is to be used fully and efficiently and, on the other hand, the need to employ fully modern production capacity so that resulting low prices will promote consumption. The second problem before the committee was the opportunity presented to Europe, "now that the steel shortage is over," to develop overseas markets for steel, particularly through offering reasonable prices and stable sources of supply. The secretariat of the United Nations Economic Commission has in preparation detailed studies of both these problems. It is stated that these studies will be published in the spring.

Other matters to which the committee turned its attention were the recent developments in the international scrap market, the requirements and availabilities of raw materials for iron and steel production this year, and steel production and consumption trends in 1952. The secretariat of the Commission has been asked by the Governments represented on the committee to make an assessment of the scrap "reservoirs" in Europe over the next decade. Such an assessment, it was suggested, would provide a useful basis for future planning, particularly with respect to iron ore, coking coal and blast-furnace programmes, and provide a basis also for ensuring healthy conditions in the European scrap market.

Foundry Regulations

The Minister of Labour has announced that he proposes to make under Sections 46 and 60 of the Factories Act, 1937, some special regulations applying to iron and steel foundries. Towards the end of last year a Private Members' Bill, entitled the Foundry Workers (Health and Safety) Bill, was introduced into the House of Commons with a view to the improvement of working conditions in ironfoundries. It will be recalled that the Bill received a second reading on December 12th last, but was subsequently withdrawn. It has now been stated that in the light of discussions with representatives of interested industrial organisations which arose out of the circumstances attending the introduction and withdrawal of the Bill, the Minister of Labour has decided to initiate forthwith the statutory procedure for making special regulations under the Factories Acts in regard to the subject matters of that Bill, and to extend the scope of the proposed regulations to steel foundries as well as ironfoundries.

The draft regulations, which are called the Iron and Steel Foundries Regulations, 1953, contain requirements concerning the safety, health and welfare of foundry workers and include provisions as to gangways, the removal of dust and fumes, protective clothing, bathing facilities, clothing accommodation and the stacking and storage of equipment, tools, &c. These draft regulations are obtainable at H.M. Stationery Office. Any objections to them, by or on behalf of persons affected, must be submitted to the Minister on or before March 31st. The objections must be in writing and must state the specific grounds of objection, and the omissions, additions or modifications suggested. They should be addressed to the Ministry of Labour, 8, St. James's Square, London, S.W.1.

Notes and Memoranda

Rail and Road

ULSTER TRANSPORT AUTHORITY.—The Northern Ireland Minister of Commerce has invited Mr. G. B. Howden, M.I.C.E., to become chairman of the Ulster Transport Authority on the completion of the term of office of Mr. J. Sydney Rogers. When Mr. F. A. Pope resigned the chairmanship of the Authority in May, 1951, on becoming a member of the British Transport Commission, Mr. Rogers accepted the Minister's invitation to act as chairman until more permanent arrangements could be made. It is hoped that Mr. Howden will take over his duties as chairman on April 1st next.

REPORT ON A RAILWAY COLLISION IN THE SCOTTISH REGION.—The report has now been published on the results of the inquiry into the collision between two passenger trains which occurred on August 18th last, in the tunnel between Dalmarnock and Bridgeton Cross stations on the Glasgow Central low level line. In this collision one passenger and three railwaymen were slightly injured and the damage to rolling stock was negligible. The inquiry revealed, however, serious irregularities, and the investigating officer, Colonel R. J. Walker, states that the irregular actions of a signalman in his tampering with an instrument destroyed the adequate protection afforded by the installation and caused the collision.

Air and Water

INTERNATIONAL CHAMBER OF SHIPPING.—At a meeting of the International Chamber of Shipping, held on January 21st, Sir Colin Anderson was re-elected chairman and Mr. Lief Hoegh, C.B.E., of the Norwegian Shipowners' Association, was re-elected vice-chairman, while Monsieur Francis Fabre, of the French Shipowners' Association, was elected to succeed Mr. D. A. Delprat as joint vice-chairman.

PROCEEDINGS OF A CONFERENCE ON WATER RESOURCES.—We have received a copy of the proceedings of the conference on water resources, held by the division of the State Water Supply, Illinois, U.S., in October, 1951, on the occasion of the inauguration of the Water Resources Building at Urbana. A considerable number of papers and discussions are printed in the volume of the proceedings, under the headings of hydrology treatment and radar weather.

WHALING DEVELOPMENTS. — Inadequate marking methods are responsible for the loss of about 10 per cent of all the whales killed and to solve this problem Venner, Ltd., has produced a lightweight marker buoy. This is a scaled down version of the company's radio transmitting dahn buoy and is fabricated from aluminium alloy and the prototype weighs 65 lb. The buoy has a transmitting range of 30 miles and a transmission time of twenty-two hours and it is expected that the production models will be 10 lb lighter than the prototype.

LINERS TO BE LAUNCHED.—On Thursday, May 14th, two 28,000-ton liners are to be launched. They are the "Orsova," which is under construction at the Barrow yard of Vickers-Armstrongs, Ltd., for the Orient Line, and the "Arcadia," which John Brown and Co., Ltd., is building for the P. and O. line. The "Orsova" will be launched by Lady Anderson, the wife of Sir Colin Anderson, a director of the Orient Steam Navigation Company, and Mrs. Donald Anderson, the wife of the deputy chairman of the P. and O. Steam Navigation Company will name the "Arcadia."

AIR TRAFFIC, DECEMBER 1952.—Air transport movements at United Kingdom aerodromes in December, 1952, numbered 11,770, nearly 5 per cent more than in December, 1951. Passengers handled numbered 179,400, being over 21 per cent more than in December, 1951, and freight on and off-loaded amounted to 3310 short tons, a decrease of 4 per cent. Post office mail handled during the month increased slightly to 1660 tons. At London Airport there were 2430 air transport movements (an increase of over 10 per cent on December, 1951), and 54,000 passengers were handled (18 per cent increase). Northolt Airport recorded a decrease of nearly 8 per cent, with 2600 movements, and passengers handled decreased by 3 per cent to 40,800. Airports at which passenger traffic increased considerably over December, 1951, were Glasgow (Renfrew) 10,300 (48 per cent increase); Manchester (Ringway) 8800 (42 per cent increase); Prestwick 11,500 (40 per cent increase). Edinburgh (Turnhouse) passengers increased by 375 per cent to 2900. Jersey Airport handled 6800 passengers (7 per cent increase) and Guernsey 4700 (20 per cent increase).

JOINT CONFERENCE ON INDEXING OF AERONAUTICAL INFORMATION.—The Aslib Aeronautical Group has received a request from the Advisory Group for Aeronautical Research and Development (Agard) of the North Atlantic Treaty Organisation to participate jointly in the Aslib Group's second annual conference. The Joint Conference will be held from Friday, March 27th, until Tuesday, March 31st, at the College of Aeronautics, Cranfield. Delegates will assemble on the Friday evening. The annual general meeting of the Aslib Aeronautical Group will be held on Saturday and there will be a session on the cataloguing of aerodynamic data, with special reference to the Dutch scheme set out in N.L.L. Report No. 116. The Conference dinner will be held on Saturday evening, preceded by a cocktail party. On Sunday there will be a full-day discussion on a common international system for indexing, abstracting and cataloguing all aeronautical reports. The final meeting, on Tuesday, March 31st, is for Agard delegates only, to decide on the action to be taken on the matters discussed. The chairman on Sunday, Monday and Tuesday will be Professor A. A. Hall, director of the Royal Aircraft Establishment. The conference fee will be £1 5s., including preprints, membership of the College club, and transport from Bedford railway station. Board and accommodation will be £1 5s. per day. Further particulars may be obtained from Mr. C. W. Cleverdon, College of Aeronautics, Cranfield, Bletchley, Buckinghamshire.

Miscellanea

SWISS INDUSTRIES FAIR.—It is announced that the Swiss Industries Fair is to be held at Basle from April 11th to April 21st, next. Preliminary notices state that this year there will be more than 2200 exhibitors, whose products will be arranged in seventeen industrial groups in fourteen halls, covering an area of over a million square feet.

SCALE OF CHARGES FOR CONSULTING STRUCTURAL ENGINEERS.—We have received from the Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, a booklet with the above title which gives details of the scales of charges and methods of payment usually in operation amongst consulting structural engineers; this scale became operative from April, 1952. The price of the booklet is 1s. 3d.

WORKS MAGAZINE EDITORS' CONFERENCE.—The Industrial Welfare Society is arranging a conference for editors of works' magazines, the general theme for which is "Productivity." This conference is to be held at the Hydro Hotel, Llandudno, from Friday evening, March 20th, to Monday morning, March 23rd. Mr. T. Fassam, publications officer of the Industrial Welfare Society, will preside. The fee for the conference is £8 8s. a delegate from member firms and £9 9s. a delegate from non-member firms. Applications should be made to the Conference Secretary of the Industrial Welfare Society, Robert Hyde House, 48, Bryanston Square, London, W.1.

CAREERS BOOK ON WELDING AND CUTTING.—A new illustrated booklet entitled *The Welder and Cutter* has been published in the Choice of Careers Series issued by the Central Youth Employment Executive. This book describes graphically how welding plays a large part in shipbuilding, boilermaking, motor and aircraft manufacture, structural work and most other branches of engineering. Both electric arc welding and gas welding are covered, and there is a separate section on cutting. The booklet, designed to help boys leaving school, is likely to be of interest also to parents, teachers and others who help young people to choose their careers, as well as to all in industry who are concerned with the recruitment, allocation and training of young entrants.

A SIMPLIFIED LIMIT SYSTEM.—We have received from the Pilot Plug Gauge Company, Ltd., of 9, Warwick Avenue, Coventry, particulars of a simplified limit system, which it has evolved and which is designed to provide tolerances suitable for the whole field of engineering. This system, known as the "Pilot +2" limit system, was evolved following investigations on the tolerances of nearly 10,000 limits on gauges of recent manufacture. In it the unilateral system used is based upon a standard hole and the diameter of the shaft is varied to give the requisite fit, as opposed to a bilateral system in which the shaft is made to a standard and the hole varied to provide the fit. The principles of the system can be explained fairly readily, and once its rudiments are appreciated, any tolerance for any class or diameter of hole can be calculated mentally or even memorised.

A STRUCTURAL FIRM'S ACHIEVEMENTS.—We have received from Braithwaite and Co. (Engineers), Ltd., Dorland House, Regent Street, London, S.W.1, a volume which presents pictorially numerous examples of the structures erected by the firm and its associated companies. The various techniques with which the company has been particularly concerned, such as the use of "Screwcrete" piling, pressed steel tanks and welded structures, are all exemplified in a number of illustrations. A particularly interesting section depicts some of the emergency bridges and other works carried out during the last war, in the execution of which no little technical ingenuity was shown. The various sections of this pictorial work are entitled: bridges; piers, wharves and jetties; "Screwcrete" foundations; pipelines; power stations; steel-framed structures; steel towers and pylons, welded structures; railway wagons; pressed steel tanks; and World War II, 1939–45.

POST OFFICE TELEPHONES.—The General Post Office says that since January 1, 1946, the number of telephones throughout the country has increased by over 1,912,000, bringing the total to 5,814,465 in use at the end of September, 1952. During the year ended March 31, 1952, the number of effective local telephone calls totalled 3230 million and there were 262 million trunk calls. Outgoing calls in the Continental services amounted to 1,406,000 and 84,000 outgoing calls were made on the international radio telephone service. At the end of November last there were 18,512 telephone circuits, over 25 miles in length, in use in the public network, and 793 of these had been added during the preceding twelve months. At March 31, 1952, there were 5881 local telephone exchanges throughout the country. But the expansion of the telephone service indicated by these figures has not been sufficient to satisfy the public demand for facilities. At the beginning of 1946 nearly 300,000 applicants were awaiting service and by the end of 1949 the figure of outstanding applications had increased to 548,500. Since then it has progressively declined and at the end of last September there were 447,986 outstanding applications for service.

LUBRICATION OF OIL ENGINES.—Shell Mex and B.P., Ltd., has issued a book entitled *The Lubrication of Oil Engines*, which is the sixth in the series and is a concise survey of modern practice. Chapter 1 is concerned with different engines and cycles of operation, including single and double-acting, four-stroke and two-stroke engines and the opposed piston, two-stroke engine, all of which are illustrated by sectional elevation drawings. Both air and mechanical fuel injection systems are described, together with notes upon several combustion chamber designs and accompanied by a number of line drawings giving details. Then, following a short chapter on hot bulb and dual fuel engines, scavenging and pressure charging are discussed and illustrated and the various systems are outlined. Piston cooling is referred to and various methods are illustrated by drawings, while the next chapter is devoted to the arrangements for the application of the oil to bearings, cylinders, camshafts and valve gear and air compressors. The service performance and selection of engine lubricants is next considered and is followed by notes upon the purification of the oil in which information is given with regard to full-flow and by-pass purification, by-pass filtration and centrifuging and batch purification and also methods of reclamation. Operating troubles are classified into eleven groups, ranging from high oil consumption to bearing wear and failure, and each is discussed in turn. There is a chapter concerned with oil engine power transmission in which reference is made to road and rail traction, stationary service and marine propulsion and this is followed by brief notes upon Shell lubricants for oil engines and transmission units and a viscosity conversion table.

Personal and Business

MESSRS. KENNEDY AND DONKIN state that their Manchester office has been moved to 64, Royal Exchange, Manchester, 2 (telephone, Deansgate 7151).

HICK, HARGREAVES AND CO., Ltd., Bolton, states that Mr. John Aspinall, M.I.Mech.E., works director, has been appointed assistant managing director.

THE NATIONAL COAL BOARD announces the appointment of Dr. R. J. Morley as Director-General of Carbonisation, in succession to Mr. L. O'Connor.

MR. D. T. BARRITT, Mr. H. Clarke and Mr. J. P. V. Woollam have been appointed joint managing directors of Simon Carves, Ltd., Cheadle Heath, Stockport.

THE BRITISH ALUMINIUM COMPANY, Ltd., has moved its Leeds branch office to Martins Bank Chambers, Vicar Lane, Leeds, 1. Mr. A. E. Heeley continues as branch manager.

THE HOFFMANN MANUFACTURING COMPANY, Ltd., has moved its Cardiff office and stockroom to 121, Cathedral Road, Cardiff (telephone: Cardiff 30133; telegrams: "Hoffmann, Cardiff.")

DUNLOP, Ltd., announces the retirement, owing to ill-health, of Mr. W. W. Foster, general works manager at Fort Dunlop. His successor is Mr. E. E. Quinton, general works manager at the Speke factory.

THE SONDES PLACE RESEARCH INSTITUTE, Dorking, Surrey, has opened a new section of its laboratories for the assaying and analysis of ores and metals and the testing of minerals. Mr. E. W. Dawson is taking charge of the work.

LANCASHIRE DYNAMO AND CRYPTO, Ltd., announces the retirement of Mr. G. S. Helme, A.M.I.E.E., manager in Scotland for the past twenty-one years. Mr. Helme will continue to serve the company as a consultant. His successor as manager in Scotland is Mr. W. J. A. Gemmell.

THE POWER GAS CORPORATION, Ltd., Stockton-on-Tees, announces the conclusion of an arrangement with Chemiebau Dr. A. Zieren G.m.b.H., Nieder-Marsberg, Germany, to manufacture and sell a complete range of sulphuric acid plant and associated equipment to Chemiebau designs.

LEYLAND MOTORS, Ltd., announces the appointment of Mr. Norman Tattersall, M.I.Mech.E., as chief engineer to the company. Dr.-Ing. A. Mueller has been appointed chief development and research engineer in charge of a new division which has been created within the company's organisation for long-term development.

THE BRITISH THOMSON-HOUSTON COMPANY, Ltd., Rugby, announces the retirement of Mr. E. Sayers, manager of the aero and auto equipment sales department. He has been in the company's service for forty-eight years. His successor is Mr. V. A. Higgs, A.M.I.E.E. who has been assistant manager of the department for the past two years.

NEWMAN INDUSTRIES, Ltd., Yate, Bristol, announces the following appointments in its electrical division; Lieut.-Colonel E. A. Barr-Dudley, A.M.I.E.E., home sales manager; Mr. A. N. D. Kerr, A.M.I.E.E., London sales manager; Mr. A. C. Coad, Manchester office manager; Mr. V. P. Henderson, London sales staff; Mr. M. C. de Roemer, sales engineer.

BRYNMAWR RUBBER, Ltd., is reorganising its subsidiary selling company, Brynmawr Rubber (Sales), Ltd. Until further notice, all correspondence and inquiries should be addressed to Brynmawr Rubber (Sales), Ltd., at Brynmawr, Breconshire. By mutual arrangement, Major H. L. Anderson and Mr. T. T. Ottowell, the retiring directors of Brynmawr Rubber (Sales), Ltd., are resuscitating their business and retaining their office at 70, Finsbury Pavement, London, E.C.2, from which address they will operate under the name Hemisphere Rubber Company, Ltd.

British Patent Specifications

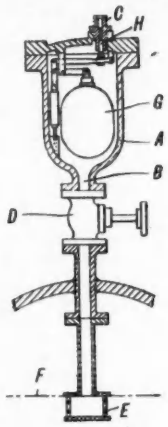
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

STEAM GENERATORS

685,400. November 8, 1950.—HIGH WATER LEVEL SAFETY CONTROL DEVICES, Stewart Wilson and Alexander Stephen and Sons, Ltd., of Linthouse, Govan, Glasgow.

The invention relates to high water level safety control devices for use with the steam drums of steam generators, particularly where the generator furnace is fitted with liquid or gaseous fuel burners supplied with fuel through a stop valve in the fuel supply pipeline. The steam drum may be fitted with two safety control devices, one operative at the low water level to regulate the fuel supply to the burners of the steam generator, and the other operative at high water level to regulate the feed water supply to the steam drum. Referring to the drawing, the device comprises a vessel *A* having an inlet passage *B* at its lower end and closed at its upper end by means of a cover having a tubular outlet connection *C* passing through it. The vessel communicates at its lower end through a normally open stop cock *D* with a tubular connection which passes through and is sealed in the top of the steam drum, as shown. Depending from the inlet connection is an inlet tube which terminates in a box or cage *E* with perforated sides. The cage is fixed so that the top of the perforations is on the same line as the high water line *F* of the steam drum. The vessel *A* is fitted with a float *G*, which controls a valve *H* in the outlet connection *C* and the vessel is connected directly to the steam drum through one opening only, i.e. the inlet passage *B*. The vessel *A* during normal working is completely filled with steam from the boiler of the drum. Consequently the float *G* sinks and closes the valve *H*. The vessel remains completely filled with steam until the level of water in the drum rises to the top of the perforations in the cage *E*, when the steam supply is cut off. As the vessel then cools, the steam condenses and the vessel and the tube fill with water from the water space of the drum. On the float then becoming effective, the valve *H* is fully opened and water under pressure in the drum escapes through the outlet connection *C*. The escaping water is arranged to operate a feed water control valve to shut off the supply to the drum. A convenient form of feed water control valve for the purposes of the invention is also illustrated in the specification.—*January* 7, 1953.

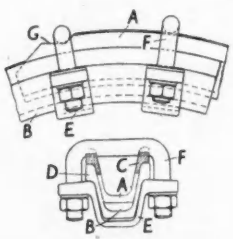


No. 685,400

MINING ENGINEERING

685,477. May 2, 1950.—MINE ROOF SUPPORTS, Margot von Linsingen, 33, Bluerherstrasse, Bochum, Germany, trading as Bochumer Eisonhuette Heintzmann and Co.

The invention relates to a connection for members of trough cross-section overlapping one another and is particularly intended for arch supports for mine galleries. The connecting means provided



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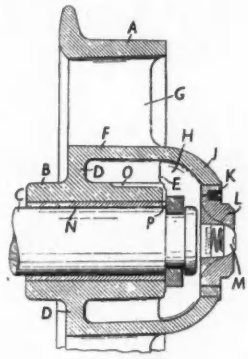
is designed to prevent the members from being separated but allows a longitudinal displacement under the roof pressure. As illustrated in the drawing the arch consists of similar members *A* and *B* of channel section. The members rest with their flanges *C* and *D* one on top of the other, whilst a clearance is left between their base or middle portions. The two members are connected with each other by a strap *E* and a stirrup bolt *F*. The flanges of the inner member *A* have notches *G* near the end of which one of the stirrup bolts rests. This notch has an inclined surface sloping downwards towards the end of the inner member. Near the other end of the overlap of the members a similar connecting device is provided. The invention is designed for the arch support for mine galleries, but it is also usable for iron or steel sections for use above ground.—*January* 7, 1953.

685,947. July 28, 1950.—SELF-OILING WHEELS, Samuel Osborn and Co., Ltd., Clyde Steel Works, Wicker, Sheffield, 3; and Frank Ashcroft Martin, of the company's address.

The invention relates particularly to wheels for pit tubs and like vehicles which are subjected to heavy usage. The drawing shows the self-oiling wheel, of which *A* is the flanged rim and *B* the hub carrying an axle *C*. Integrally connected at *D* with the hub and spaced from it by radial webs *E* is a boss *F* which is connected with the flange by curved arms *G*. A lubri-



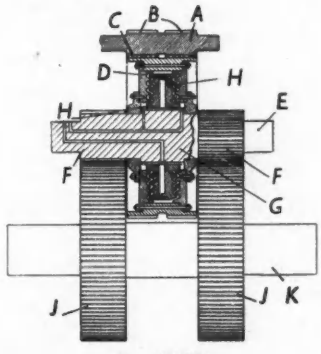
No. 685,947

cant-containing reservoir *H* is formed and extends into a domed extension *J* to the boss *F*. The domed extension is provided with a central orifice, into which a mild steel ring *K* is shrunk. This ring is threaded and fitted with a closure cap *L* which carries a lubricating nipple *M*. A phosphor-bronze bush *N* is fitted between the axle and the hub. Lubricant passages *O* spaced round the hub communicate with grooves *P* provided in the end of the bush *N*.—*January* 14, 1953.

POWER TRANSMISSION

684,886. December 22, 1950.—FRICTION CLUTCHES, Aktiebolaget Gotaverken, Gothenburg, Sewden.

The clutch described in the specification may be used in transmission between a high-speed engine shaft and a drive shaft for a vehicle. In the drawing, *A* is the shaft, which may be directly connected to the shaft of a turbine. The shaft *A* has two gear rims *B*, which engage two gear rims *C* and are rigidly connected to each other. The rims *C* are secured to discs *D* constituting the lateral parts of a gear wheel. On a shaft *E* there are formed two pinions *F*, and between



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these pinions there is provided a portion *G* of a greater diameter than the outer diameter of the pinions. The portion *G* is splined and has mounted on it two clutch discs *H* which are axially displaceable on the shaft *E*, but not rotatable. The lateral parts *D* and the clutch discs *H* have annular projections and recesses adapted to co-operate with each other. The pinions *E* mesh with gear wheels *J* on a shaft *K*, which may constitute the drive shaft of a locomotive. The gear wheels can mesh with further gear wheels running in the opposite direction with respect to the pinions for reversing the direction of running. In this case a further shaft corresponding to shaft *E* and a second clutch of the type described may be provided. If fluid under pressure is supplied to the passages between the clutch discs they are forced from each other into engagement with the parts *D*. If fluid under pressure is supplied to the central passages the discs are forced against each other so as to disengage the clutch, suitable drain pipes for the fluid being provided.—*December* 24, 1952.

METALLURGY

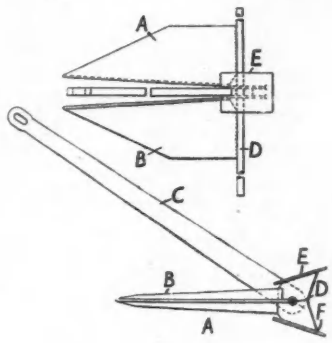
688,797. September 22, 1950.—TREATMENT OF DEFECTIVE METAL CASTINGS, Industrial Impregnations, Ltd., 120, High Street, Brentford, Middlesex. (*Inventor: Percy Joseph Young.*)

According to the invention, a method of treating defective metal castings having blowholes or similar cavities comprises preparing a workable mix from a powdered metal or alloy which is the same as, or closely resembles, the metal of the casting and a thermosetting resin in the uncured or partly cured state, filling the cavity with the mix and heating the casting to a temperature which will cure the resin component of the mix. Preferably, the mix employed contains a high proportion of the powdered metal or alloy, for example, not less than 70 per cent by weight and preferably 90 per cent by weight. The metallic powder is intimately mixed with the resin component which is generally employed in the form of a solution or of a liquid intermediate condensation or polymerisation product in order to ensure that the mix produced will have desirable properties of being capable of being filled into a cavity with relative ease. With advantage the solution employed contains a high proportion of the resin or intermediate product. The thermosetting resins employed must be capable of withstanding the conditions of service of the casting being treated and therefore, in general, must be capable of resisting a temperature of 150 deg. Cent. Examples of the use of this method are given in the specification.—*January* 14, 1953.

MARINE ENGINEERING

686,160. October 16, 1950.—ANCHORS, Richard Stevens Danforth, 2121, Allston Way, Berkeley, California, U.S.A.

Referring to the drawings, the anchor has flukes *A* and *B*, a shank *C*, a stock *D* attached to the flukes and crown plates *E* and *F*. The flukes have reinforcing ribs or flanges formed on the edge nearest the shank, and when mounted in position the flanges extend in opposite directions. The improved crown



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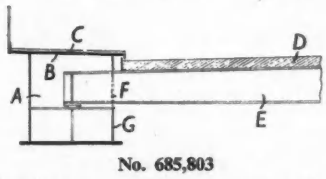
structure ensures, it is claimed, that the anchor engages bottom with great rapidity and digs into the bottom almost immediately upon contact. A modified design is also shown in the specification.—*January* 21, 1953.

STRUCTURAL ENGINEERING

685,803. December 1, 1950.—STEEL BRIDGE GIRDER STRUCTURE, Fried. Krupp Stahlbau Rheinhausen, Rheinhausen, Niederrhein, Germany.

The invention relates to steel girder structures for steel bridges which are disposed beneath the reinforced concrete platform constituting the roadway, and



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its object is so to construct such structures that the formation of cracks in the reinforced concrete platform are avoided. In a wide main box girder *A* of steel the upper boom plate *B* serves to support the platform *C* constituting a footway. The width of the boom plate *B* renders it possible to introduce without difficulty the required boom sections. The reinforced concrete roadway platform *D* rests on the steel cross girders *E* and is rigidly connected with them to form a composite girder. The ends of the steel cross girders *E* extend through openings *F* in

the inner walls *G* of the main girders *A*, and are supported inside them. In another construction described the ends of the cross girders *E* are supported on brackets which project from the inner walls *G*. The reinforced concrete roadway *D* is rigidly connected to the cross girders, which lie fairly close to one another and forms with them a composite girder having a different resistance to bending in two directions. The cross girders *E* and the concrete roadway are so supported that they can move longitudinally. This construction prevents the occurrence of tensile stresses as the result of shrinkage, which might lead to cracks in the concrete.—*January* 14, 1953.

Codes of Practice

MECHANICAL REFRIGERATION

Code 406 (1952). The code opens with notes on specifications and testing of plant, and parts that follow deal with safety and thermal insulation.

Safety is considered from the point of view of securing safeguard to life, health and property, and recommendations are given to ensure adequate strength of plant and protection against excessive pressures. Advice is also included on the provision of devices to secure protection against damage arising from low evaporating temperatures and from freezing from cooling liquid. Other aspects dealt with are: the safety of electrical installation, alarm signals, choice and storage of refrigerants, and precautions against fire and accident. A section deals with inspection and testing, including a table of minimum test pressures, at works, for various components of the plant, and there are recommendations for minimum test pressures for the complete system after erection on site. The physical, toxic and explosive properties of refrigerants are given.

The final part of the code deals with the design, construction, installation, testing and inspection of insulation to assist in maintaining temperatures below the ambient temperature. Points are set out on which consultation between interested parties is necessary in the early design stages. Guidance is given on the calculation of the thickness of insulation required, and tables are included giving recommended resistances for various temperature differences, the characteristics of bitumen (for erection purposes) and of some commonly used types of insulating material. Details of water vapour transmittance of various materials are also given and a chart is provided for determination of thermal resistance required on flat surfaces to prevent condensation.

The dangers of structural damage due to expansion and contraction and to frost heave are considered and recommendations made to circumvent them. A summary is included of temperature and humidity observations for each month of the year at each of eight meteorological stations in the United Kingdom. The code carries the usual warning that, in the present abnormal conditions, it may not be practicable to carry out all the recommendations. Price 5s. from the British Standards Institution, 24-28, Victoria Street, S.W.1.

THE STRUCTURAL USE OF TIMBER IN BUILDINGS

Code 112. The Council for Codes of Practice for Buildings has now issued in final form Code 112, "The Structural Use of Timber in Buildings," which deals with the design, fabrication and erection of structural timber work. It is based on the principles of engineering design and on data established by research, and gives recommendations for the quality of materials, the moisture content of timber for various purposes and the permissible stresses appropriate to particular conditions of loading and service, applicable to timber when used either in simple solid members or as parts of built-up structures incorporating other materials. Design data for the use of nails, screws, bolts, connectors and adhesives are also included. Recommendations are given for a method of test for components or assemblies of unconventional design which may not be readily amenable to detailed analysis.

Sub-Code 112.100, which is incorporated in the main code, deals with the preservation of timber by wood preservatives against fungal and insect attack, but not with protection against fire or mechanical damage, nor with the methods of minimising the decay hazard of untreated timber by means of seasoning, ventilation and painting. It gives recommendations for the structural use of preserved timber in buildings and the circumstances in which the use of preservative treatments is desirable. Guidance is given in the choice of preservative, the preparation of timber for treatment, the methods of treatment and the conditioning of timber after treatment. A table is given relating types of preservatives and methods of application to the various uses of timber.

The code, CP 112 (1952), carries the usual warning that, in the present abnormal conditions, it may not be practicable to carry out all the recommendations. Copies may be obtained from the British Standards Institution, 24/28, Victoria Street, S.W.1, price 10s. 6d.

Catalogues

ROBERT JENKINS AND CO., Ltd., Rotherham.—Illustrated catalogue entitled "Welded Fabrications."

NEGRETTI AND ZAMBRA, Ltd., 122, Regent Street, London, W.1.—Catalogue No. R/30, dealing with automatic controllers.

HEAD, WRIGHTSON AND CO., Ltd., Teesdale Ironworks, Thornaby-on-Tees.—Wagon department catalogue, illustrated.

THE CEMENTATION COMPANY, Ltd., Bentley Works, Doncaster.—Brochures dealing with cast iron welding repairs by the Gussolite process.

MAYOR AND COULSON, Ltd., Bridgeton, Glasgow, S.E.—Booklet No. 64, describing driving gears for belt conveyors from 7 h.p. to 200 h.p.

KEITH BLACKMAN, Ltd., Mill Mead Road, Tottenham, London, N.17.—Publication No. 23, giving details of "Tornado" paddle wheel type fans.

ADAM MACHINE TOOL COMPANY, Ltd., Hanley Road, Finsbury Park, London, N.4.—Leaflet describing "Tavannes" thread measuring micrometers.

ALLEN WEST AND CO., Ltd., Brighton, 7.—Publication No. 1746, showing examples of standard contactor starters and special assemblies for control of machine tools.

ROCKWELL MACHINE TOOL COMPANY, Ltd., Welsh Harp, Edgware Road, London, N.W.2.—Booklet illustrating the range of machine tools for which Rockwell's are agents.

GOODENOUGH CONTRACTORS' MACHINERY, Ltd., 70/72, London Road, Twickenham, Middlesex.—Catalogue illustrating and describing automatic self-priming centrifugal pumps.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., Norfolk House, Norfolk Street, London, W.C.2.—Publications giving details of "Bicalex" winding wires and "Bestos" A.V.C. cables.

SIR W. G. ARMSTRONG, WHITWORTH AND CO., (IRONFOUNDERS), Ltd., Close Works, Gateshead-upon-Tyne.—Leaflet F122, giving an introduction to the Kue Ken jaw and gyratory crushers.

BLAW KNOX, Ltd., 90/94, Brompton Road, London, S.W.3.—Publications BK-171, "BK-40 Scraper"; BK-143/2, "BK-80 Scraper"; BK-172, "BK-90 Scraper"; and BK.144/1, "BK-120 Scraper."

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on or before the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Mon., Feb. 9th.—CENTRAL LONDON BRANCH: St. Ermin's Hotel, Caxton Street, S.W.1, "Corrosion and Cathode Protection," G. G. Portch, 6.45 p.m.——N.W. LONDON BRANCH: Prince of Wales Hotel, Kingsbury, Brains Trust, 8 p.m.
Tues., Feb. 10th.—BOLTON BRANCH: Balmoral Hotel, Bradshawgate, Bolton, Lecture, 7.30 p.m.
Wed., Feb. 11th.—BRADFORD BRANCH: Midland Hotel, Bradford, "Factory Maintenance," J. W. White, 7.30 p.m.——PRESTON BRANCH: Bull and Royal Hotel, Preston, "Aluminium Cables," F. T. Aldridge, 7.30 p.m.
Fri., Feb. 13th.—CREWE BRANCH: Copeland Arms Hotel, Glebe Street, Stoke, "A.c. Motors and Control Gear," T. C. Riches, 7.30 p.m.——LIVERPOOL BRANCH: Lecture Theatre Service Centre, 9, Whitechapel, Liverpool, "Electronics in Industry" Mr. Hickman, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Feb. 11th.—LONDON SECTION: School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, W.C.1, "Modern Trends in Communications Materials," L. A. Thomas, 6.30 p.m.——N.E. SECTION: Institute of Mining and Mechanical Engineers, Neville Hall, Westgate Road, Newcastle upon Tyne, "Design Considerations of a Commercial F.M. Receiver," F. H. Beaumont, 6 p.m.

ENGINEERS GUILD

Mon., Feb. 9th.—W. MIDLANDS BRANCH: Imperial Hotel, Temple Street, Birmingham, Films "A Tall Order," "Failure of Tacoma Narrows Bridge," "A River to Cross," 6.30 p.m.
Fri., Feb. 13th.—METROPOLITAN BRANCH: Caxton Hall, Caxton Street, London, S.W.1, Discussion on "The Engineer and International Trade," introduced by W. Robson Brown, 6 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., Feb. 10th.—Church Institute, Albion Street, Hull, "Aircraft Developments," R. D. Boot, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

To-day, Feb. 6th.—BATH AND BRISTOL CENTRE: S.W. Electricity Board Lecture Theatre, Old Bridge, Bath, "Fluorescent Street Lighting—The First Five Years" H. E. G. Watts, 7 p.m.——HUDDERSFIELD GROUP: Electricity Showroom, Market Street, Huddersfield, "Sodium Lamps and Their Applications," A. W. Gostt, 7.15 p.m.
Tues., Feb. 10th.—SESSIONAL MEETING: Lighting Service Bureau, 2, Savoy Hill, London, W.C.2, "Shop Window Lighting," A. W. Jervis, 6 p.m.
Thurs., Feb. 12th.—MANCHESTER CENTRE: N.W. Electricity Board, Town Hall Extension, Manchester, "Lamps and Lighting for Inspection," H. R. Ruff and H. E. Bellchambers, 6 p.m.

INCORPORATED PLANT ENGINEERS

Mon., Feb. 9th.—DUNDEE BRANCH: Mathers Hotel, Dundee, "The Manufacture of Plate Glass" 7.30 p.m.
Tues., Feb. 10th.—E. LANCASHIRE BRANCH: Engineers Club, Albert Square, Manchester, "Instrumentation and Automatic Control for Medium and Small Boilers," Mr. Klepp, 7.15 p.m.
Wed., Feb. 11th.—E. MIDLANDS BRANCH: Welbeck Hotel, Nottingham, "An Approach to Maintenance—the Report of the U.K. Specialist Team on Plant Maintenance," H. G. Hilton, 7 p.m.
Thurs., Feb. 12th.—NEWCASTLE UPON TYNE BRANCH: Roadway House, Oxford Street, Newcastle upon Tyne, "Application of Prestressed Concrete," D. W. Cooper, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Wed., Feb. 11th.—LANCASHIRE BRANCH: Engineers' Club, Albert Square, Manchester, "The Pattern Shop Cost Production Ratio and its Effects on Foundry Productivity," G. N. Gott, 7 p.m.
Thurs., Feb. 12th.—LINCOLNSHIRE BRANCH: Technical College, Lincoln, "Quantity Production of Engineering Castings," J. Burrell, 7.15 p.m.

INSTITUTE OF ECONOMIC ENGINEERING

Sat., Feb. 7th.—The Christian Institute, 70, Bothwell Street, Glasgow, "Production Incentives," J. Binnie, 10.30 a.m.
Fri., Feb. 13th.—George Hotel, Church Lane, London, N.W.9, "Trades Unions and Productivity," E. Fletcher, 7 p.m.

INSTITUTE OF INDUSTRIAL SUPERVISORS

Thurs., Feb. 12th.—LONDON CENTRAL BRANCH: Polytechnic, Regent Street, W.1, "Aspects of Factory Economics," Part I, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Tues., Feb. 10th.—85, Minories, London, E.C.3, "Atomic Propulsion, with special reference to Marine Propulsion," Sir John Cockcroft, 5.30 p.m.
Thurs., Feb. 12th.—Borough Polytechnic, London, S.E.1, "Photo-Elasticity," J. Ward, 7 p.m.

INSTITUTE OF PETROLEUM

Wed., Feb. 11th.—26, Portland Place, London, W.1, "Entry into Oil Operations in Western Canada," C. S. Lee and R. O. Young, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Tues., Feb. 10th.—MIDLANDS CENTRE: Crown Inn, Broad Street, Birmingham, "Organisation for the Maintenance of a Large Fleet," J. W. Tayler, 7.30 p.m.
Wed., Feb. 11th.—E. MIDLANDS CENTRE: Mechanics Institute, Nottingham, "Specialised Vehicles for Road Transport," L. D. Watts, 7.30 p.m.
Thurs., Feb. 12th.—WESTERN CENTRE: Grand Hotel, Bristol, "Organisation for the Maintenance of a Large Fleet," J. W. Tayler, 7.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Tues., Feb. 10th.—Geological Society, Burlington House, London, W.1, "Heat Transfer from Luminous Gas Flames in Vertical Tubes," S. R. Tailby and Muhammed Aly Saleh, 5.30 p.m.
Thurs., Feb. 12th.—N.W. BRANCH: Engineers' Club, Albert Square, Manchester, "Pneumatic Conveying: Part I, The Pressure Drop During Horizontal Conveyance," D. M. Newitt, J. F. Richardson, R. H. Clark and D. E. Charles.

INSTITUTION OF CIVIL ENGINEERS

Tues., Feb. 10th.—STRUCTURAL AND BUILDING MEETING: Great George Street, Westminster, London, S.W.1, "Corrugated Concrete Shell Roofs," J. H. de W. Waller, 5.30 p.m.
Thurs., Feb. 12th.—N.W. ASSOCIATION: Engineers' Club, Albert Square, Manchester, "Design and Construction of a Six Million cubic feet Gasholder Foundation at Bristol," T. A. Hughes and F. W. Turner, 6.30 p.m.——MIDLANDS ASSOCIATION: James Watt Memorial Institute, Great Charles Street Birmingham, "Practical Methods in Flood Protection," W. E. Doran, 6 p.m.
Fri., Feb. 13th.—YORKSHIRE ASSOCIATION: Hull, "Practical Methods of Flood Protection," W. E. Doran, 6.15 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Feb. 10th.—39, Elmbank Crescent, Glasgow, C.2, "Cranes," J. Patrick, 6.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Feb. 9th.—INFORMAL MEETING: Savoy Place, London, W.C.2, Discussion on "Is Technical Advertising Necessary or Desirable," opened by W. Bamford, 5.30 p.m.
Tues., Feb. 10th.—JOINT MEETING: Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, "Ignition Interference with Television Reception," A. H. Ball and W. Nethercot, 5.30 p.m.
Wed., Feb. 11th.—RADIO SECTION: Savoy Place, London, W.C.2, "A Method of Designing Transistor Trigger Circuits," F. C. Williams and G. B. B. Chaplin, 5.30 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Mon., Feb. 9th.—WOLVERHAMPTON BRANCH: Crompton Grange, Compton Road, Wolverhampton, "Arc Welding," G. G. Musted, 7.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Tues., Feb. 10th.—JOINT MEETING OF THE AUTOMOBILE DIVISION WITH INSTITUTION OF ELECTRICAL ENGINEERS: Storey's Gate, St. James's Park, London, S.W.1, "Ignition Interference with Television Reception," A. H. Ball and W. Nethercot, 5.30 p.m.
Fri., Feb. 13th.—Storey's Gate, St. James's Park, London, S.W.1, Conference on Hydraulic Servo-Mechanisms, 10.30 a.m., 2.30 p.m. and 5.30 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Thurs., Feb. 12th.—LONDON MEETING: Royal Society of Tropical Medicine and Hygiene, 26, Portland Place, W.1, "Practical Safety in the Rubber Industry," G. Lynch, 5.30 p.m.; "Recent Developments in Chemical Derivatives of Rubber," C. M. Blow, 7.30 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Thurs., Feb. 12th.—11, Upper Belgrave Street, London, S.W.1, "The Strength of Brickwork," F. G. Thomas, 6 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Feb. 6th.—Townsend House, Greycoat Place, London, S.W.1, Film Evening, "Depositing Stellite with the Oxy-Acetylene Flame," 7 p.m.
Mon., Feb. 9th.—N.W. SECTION: Geographical Society, 16, St. Mary's Parsonage, Manchester, "Coal Utilisation," 7 p.m.——SHEFFIELD AND DISTRICT SECTION: Livesey Clegg House, Sheffield, "Mechanisms in Paper-Wrapping Machines," J. A. Cuckson, 7.30 p.m.

LIVERPOOL METALLURGICAL SOCIETY

Thurs., Feb. 12th.—Liverpool Engineering Society, The Temple, Dale Street, Liverpool, "Nucleation in Metals and Alloys," J. H. O. Varley, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Wed., Feb. 11th.—College of Technology, Sackville Street, Manchester, 2, "A Survey of Progress in Engineering Training," Sir Arthur P. M. Fleming, 7.30 p.m.

NEWCOMEN SOCIETY

Wed., Feb. 11th.—Science Museum, South Kensington, London, S.W.7, "Early Polishing of Diamonds and Gemstones," P. Grodzinski, 5.30 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Fri., Feb. 13th.—Mining Institute, Newcastle upon Tyne, "The Role of Non-Destructive Testing in Industry," J. D. Hislop, 6.15 p.m.

OLD CENTRALIANS

Fri., Feb. 13th.—Chez Auguste Restaurant, 47, Frith Street, London, W.1, "Concrete Technology," A. L. L. Baker, 12.55 p.m.

ROYAL AERONAUTICAL SOCIETY

Wed., Feb. 11th.—GRADUATES' AND STUDENTS' SECTION: 4, Hamilton Place, London, W.1, "The Production of Prototype Aircraft," W. Thorn, 7.30 p.m.
Thurs., Feb. 12th.—4, Hamilton Place, London, W.1, "The Application of Integral Construction to Aircraft Design and its Effect on Production Methods," E. Dixie Keen, 7 p.m.